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SHUMAN'S PROCESS AND APPARATUS FOR EMBEDDING WIRE NETTING IN GLASS.

[*Being the report of the Institute by its Committee on Science and the Arts, adopted November 1, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1893.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, by its Committee on Science and the Arts, investigating Shuman's process and apparatus for embedding wire netting in glass, finds as follows:

The object of this invention is to strengthen, or reinforce, sheets of glass of various dimensions intended to be used for roof lights, partitions, vault and pavement lights, port and deck lights, etc., by inserting a metallic netting into the body of the glass sheets at the time they are rolled

with the view of protecting the glass against fracture and of preventing fragments of fractured sheets from detaching themselves in case of accident.

The present mode of protecting glass skylights is to suspend copper wire netting immediately beneath the glass, the wire being fastened to a framework holding the glass. In situations exposed to smoke, corroding gases and other destructive influences, as in railway stations, chemical works, etc., this practice is attended with serious objections, for the reason that, in such situations, even copper and brass wire will become corroded and will then be worthless as a protection against the fall of large fragments of glass, should the skylights become broken.

The enormous extent to which wire netting is used thus to protect skylights was strikingly illustrated at the late World's Columbian Exhibition in Chicago, where 1,045,000 square feet of wire netting was placed under the glass roofs of four of the main exhibition buildings.

The use of wire netting in such a manner that it cannot be corroded and, at the same time, will reinforce and strengthen the glass (which, in the old practice, the netting does not do), would obviously be a great step in advance and one which should commend itself to architects and engineers, and the advantages of embedding the wire in the glass itself to accomplish these objects are so manifest that further comment would seem unnecessary.

In examining the prior state of the art of producing sheets of glass with metallic enclosures for the purpose of strengthening and guarding the same, the following references, bearing more or less directly on the subject, have been found and consulted.

The first invention, showing wire netting embedded in glass, is the British patent, No. 1,528, of 1855, granted to Newton for fire- and burglar-proof glass. This patent describes the depositing of a quantity of molten glass into a mould, then placing on the glass a sheet of wire gauze, then placing upon the wire another quantity of molten glass, and finally pressing the mass into a sheet. The wire is prevented from projecting beyond the glass by constructing the mould in

two parts and mounting the wire between the parts; it is claimed that several sheets of wire cloth can be thus introduced into the glass.

The British patent of Hyatt, No. 1,482, of 1871, describes a method of making glass with wire embedded in it, by casting the glass on both sides of the wire work. Hyatt proposes to bend or undulate the wire by coiling it in the form of a helix, so as to allow for expansion and contraction to avoid fracture.

The British patent granted to Lake as a communication from Becoulet and Bellet, of Paris, France, No. 9,226, of 1876, describes the following method:

"A layer of fused glass of one-half the thickness required is spread upon a table, a net work of iron wire, previously polished, is placed upon the glass, another layer of glass is placed on the wire, over which a roll is passed."

The British patent granted to John Armstrong, No. 5,701, of 1887, describes a machine for embedding wire in glass. "The ordinary table and roll is used, and in front of the roll is a guide roller, under which the wire is passed from a reel. The wire is fixed at one end of the table and brought under both rolls; the wire is pressed against the incandescent glass and partly enters it, the hot glass coming through the meshes to the upper side. The roll passes over the glass and wire, squeezing the glass out to the required thickness.

The following United States patents, Nos. 229,907, 229,928 and 222,768, of 1879, granted to Arbogast, for glass insulated electric conductors and methods of making the same, and No. 355,486, of 1887, to Thompson, for wire-embedded enamelled ware, need no special mention.

German patent No. 46,287, of 1888, to Armin Tenner, and published March 18, 1889, is next in order. This patent discloses a process similar in many respects to the early British patent of 1855.

The process is as follows: "A mass of molten glass sufficient for making one-half the thickness of the plate desired is poured into a suitable mould and then rolled or pressed; then the metal inlay is introduced, consisting preferably of wire gauze; then sufficient glass is poured on to make the

desired thickness and the whole rolled or pressed and finally tempered."

The German patent of Sievert, No. 60,560, of 1891 (published February 5, 1892), follows Tenner, but describes a different method, to wit:

"A platen is used of the shape corresponding to the size of the sheet to be made. The bottom of this platen is provided with a pattern. A pattern can be formed in strips, corrugations, facets and eyes of all kinds, so that the upper edge of this pattern forms the bed for the metal inlay to be enclosed in the glass. The metal inlay is distributed on the upper edge of the pattern, and then by pouring in the liquid glass, and, if necessary, afterwards rolling, pressing and cooling off, the glass plate is produced; then on the pouring in and penetrating of the liquid glass into the depressed pattern of the mould the metal inlay will be raised, as experiments have shown, so as to be within the mass of glass."

British patent, No. 11,039, was granted to Sievert in 1891 (published April 30, 1892), for the same process described in the German patent of 1891, with additional matter, as follows, as a modification, viz:

"A mould with a smooth bottom may be employed and the design or pattern may be formed on the lower surface of the presser or plunger which is adapted to enter the mould and press down the molten glass. In this case the wire gauze is fixed by means of pieces of string or other suitable material underneath the lower surface of the plunger, so that the gauze rests against the edges of the design and is pressed into the mould, the pieces of string immediately breaking or being burnt by the heat of the molten glass. The glass enters into the cavities of the design or pattern and acts to press the metal inclosure so far down that the latter is actually inclosed in or surrounded by the glass."

It is also stated in the specification that the glass may be pressed down by pressure or rolling so as to receive an even surface.

The Shuman patents, Nos. 483,020 and 483,021, of Sep-

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PLATE 4.—Rolling the sheet; pouring the ladle of glass on table. (American Wire Glass Manufacturing Company, Tacony, Phila.)

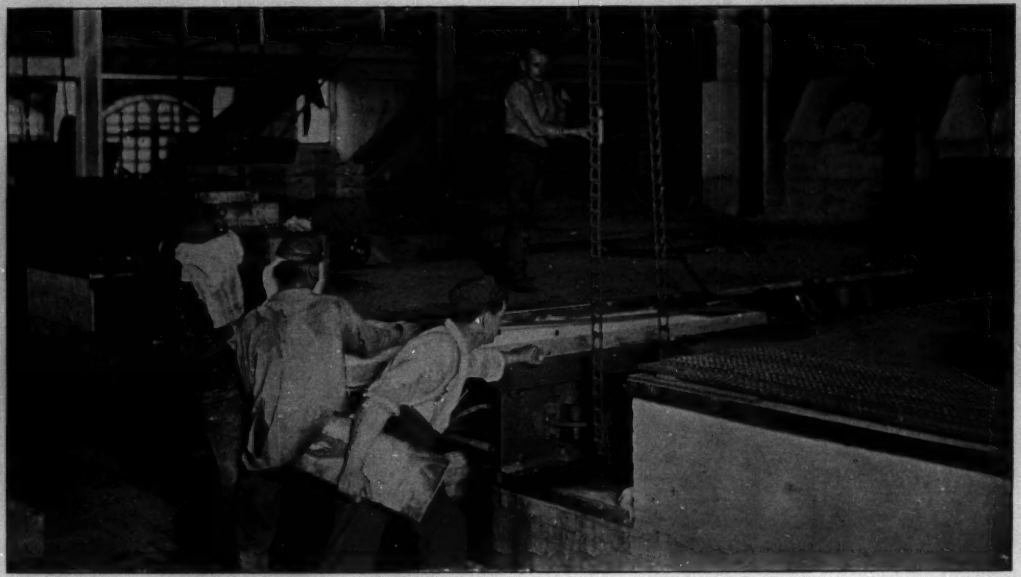

PLATE 5.—Carrying off the rolled sheet from the table. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

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tember 20, 1892, are next in order, and, as far as can be found, are the only patents granted in the United States for embedding wire netting in glass.

From the preceding sketch, it is made evident, that the idea of inserting a wire netting into sheets of glass while the glass is in a plastic condition, is by no means a new one, although its development on the commercial scale, until very recently, has not been successful.

The first attempts to put the idea into practice appear to have been made in England, some twenty years ago, by Thaddeus Hyatt, whose British patent, No. 1,482, of 1871, is referred to above, and concerning which we give the following additional details:

A section of wire netting is securely clamped in a frame of cast iron of a thickness equal to that of the glass sheet to be made. This frame is then laid upon a flat table, and sufficient glass to form a sheet poured into it. By means of a hydraulic press, part of the glass is forced through the meshes with the view of getting the glass on both sides of the netting; or, in other words, placing the netting as near as possible in the centre of the glass sheet. While this seems very simple in theory, Hyatt appears to have encountered great difficulty in forcing the glass through the meshes when a fine netting was used. To obviate this difficulty, a square or round hole was made in the centre of the section of wire netting in order to facilitate the flow of glass underneath.

The netting was thus necessarily subjected to a severe strain in forcing the glass through the meshes, and, since the metal becomes red hot by its contact with the molten glass, it will evidently stretch and sag when pressure is applied to it, thus making it impossible to keep the netting even approximately in the centre of the glass sheet. Another objection to this method is that the dimensions of the glass sheet are limited to the size of the face of the plunger of the hydraulic press. Hyatt's process was apparently found to be impracticable, and, so far as can be determined, his product never became a commercial commodity.

The patent of Armstrong (British patent, No. 5,701, of 1887) appears to come nearer to the practical solution of the problem than any which preceded those of Shuman.

In Armstrong's case a clever attempt is made to realize practically the plan of pressing a wire netting, by means of a heavy roller, into the body of a sheet of glass, and then covering the wire up in the glass by the pressure of a second roller following the first one. The mechanism by which it was attempted to carry out this idea, though embodying the elements of a useful invention, was seriously defective, and the inventor does not appear to have made any effort to improve it.

Concerning the subsequent inventions of Tenner and Sievert, it may best serve the purpose of setting forth the marked differences between them and the Shuman process, to give, in as much detail as possible, an account of the methods of procedure described therein.

In Tenner's German patent (No. 46,287, of 1888), a sheet of glass, one-half the thickness of the sheet desired, is first rolled out with a smooth roll on a flat table, in the ordinary way; then a sheet of wire netting, which has previously been made red hot, is laid upon it; another sheet of glass, one-half the thickness of the plate desired, is then rolled or pressed over the wire netting, and the whole is then subjected to hydraulic pressure, and finally annealed in the usual manner.

With this method, it is said, great difficulty has been experienced in making sheets of any considerable size; that is, of more than two feet square. It is also stated to be expensive to operate.

In Sievert's German patent (No. 60,560, of 1892), the mould in which the glass sheet is to be cast is provided with corrugations, or ridges, the upper edges of which serve as points of support to metallic bodies to be enclosed. After placing the metallic objects in position the melted glass is poured into the mould, whereupon the entering glass lifts the metallic object sufficiently, so that after the sheet is finished the metallic body will be incorporated approximately in the body of the glass sheet. This method, there-

fore, is in some sense an improvement on the method of Tenner, since it is unnecessary to produce two layers of glass, and to unite the one with the other.

In Tenner's process, the manner of incorporating the metallic netting, etc., by laying the metal upon one sheet of glass, then rolling or pressing a second sheet upon it, is liable to cause severe strains in the finished glass, and for this reason the statement that the plan is limited to the production of sheets of small size, would appear to be well founded.

Hyatt and Sievert, it will be recalled, cast the glass in a mould and incorporated the metal with the glass in one operation, and, in this respect, they represent an improvement on the process of Tenner. It is apparent, nevertheless, that in all the processes antedating Shuman's, excepting that described by Armstrong, the size of sheets produced must be limited by the difficulty of making moulds of large size.

According to a publication which appeared in the Paris *Revue Industrielle* (April 8, 1893), under the title "Les Vitres Armées" (Guarded Glass), the idea of embodying a metallic trellis work (treillage métallique), or wire netting, with the glass, is of French origin. We quote as follows:

"An application for a patent was made ten years ago by a large mirror manufacturer in the Rue de Deux-Ecus in Paris, and experiments were successfully made in the glass works of Messrs. Appert Brothers, of Clinchy, and also in the foundries of Jeaumont. The results thus obtained proved that the idea, however simple and practical it might appear, was devoid of practical results; the metallic netting suddenly assuming such a high temperature bends and twists and is with great difficulty kept in the mass of glass."

The article alleges, further, that the amount of labor required to manufacture this glass renders it so very expensive that it cannot compete with the modern process of making ordinary roofing glass. Another objection alleged in the article, is that it is absolutely necessary to know beforehand the dimensions of the required sheets, for when once made it becomes almost impossible to cut them.

Neither the French patent above referred to, nor any other reference to it, could be found, and consequently no idea of the method employed can be formed. Numerous attempts have been made in this country to incorporate a wire netting in molten or plastic glass, but here also no record exists, or could be found, of any such attempts that had met with success prior to those of Shuman.

By the Shuman process the wire netting is inserted into the glass whilst a sheet is being rolled, the wire being heated, just before its incorporation, to a temperature near the melting point of glass. The wire netting thus incorporated with the glass forms part of the sheet itself and it cannot by any means short of violence be detached or removed therefrom. Of course, such a sheet may become cracked and portions detached from and expose the wire; but even in such case, there are so many points of attachment that it would hardly be probable that sufficient corrosion could take place to seriously weaken the wire and damage the sheet, no matter how many fine cracks it might contain through which the corrosive influences could work their way to attack the metal.

The inventions of Shuman form the subject of two letters-patent of the United States, herein referred to, one covering the details of the machine, and the other the features of the process. In the following description, reference will be made to both of these specifications without special distinction, as it will be convenient to regard them for the purpose of this investigation as a single invention.

The following description of the method of manufacture, freely collated from the Shuman patents, will be understood by reference to the accompanying sheet of sectional views (*Plate 1*) of a thirty-inch glass-rolling machine, showing the same in plan, longitudinal and transverse sections, and by an inspection of the several reproductions made from photographs taken in the works of the American Wire Glass Manufacturing Company, at Tacony, Philadelphia. (See *Plates 2* to *9*.)

The sheet of drawings (*Plate 1*) represents the table upon which the glass is rolled, and which is arranged so

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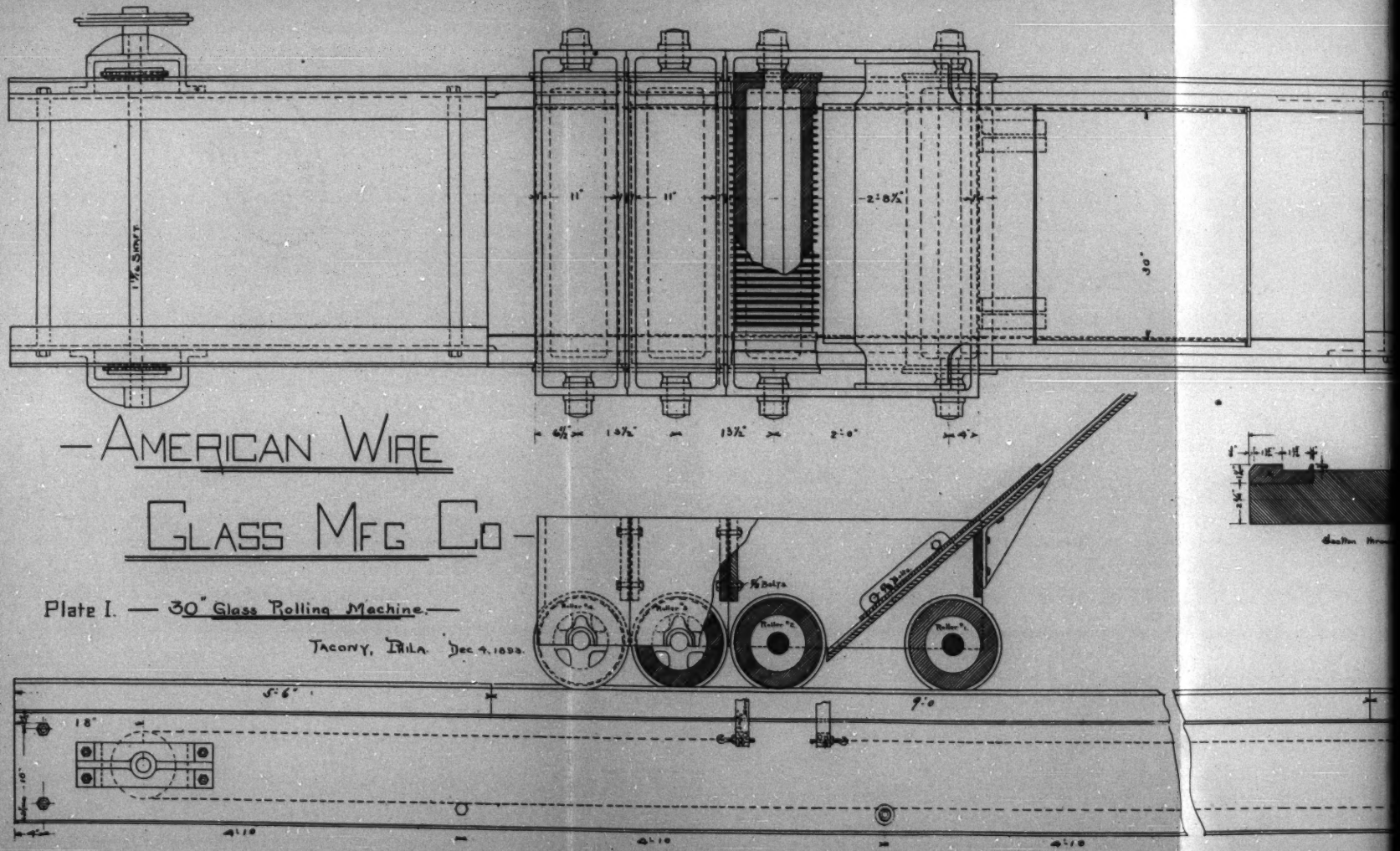
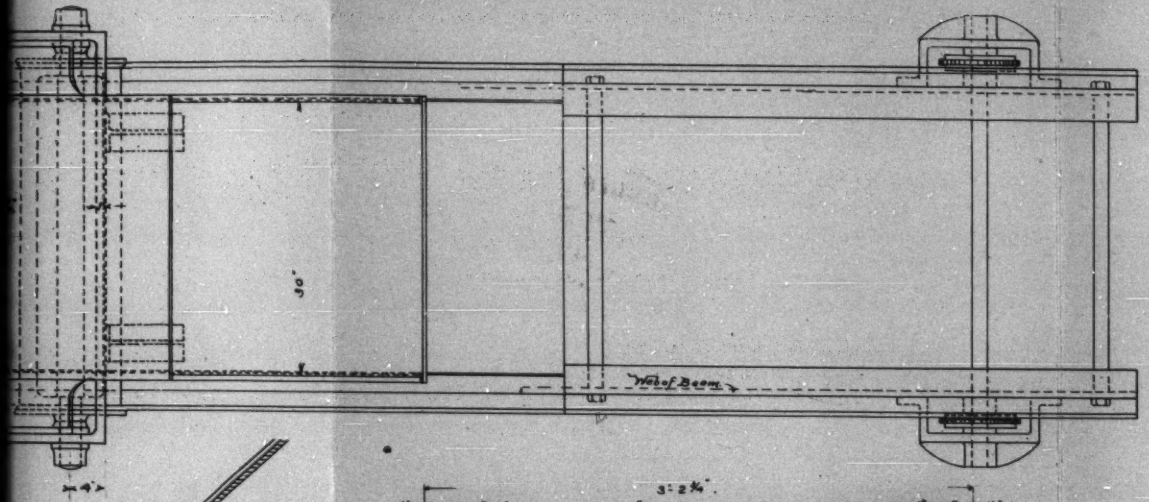
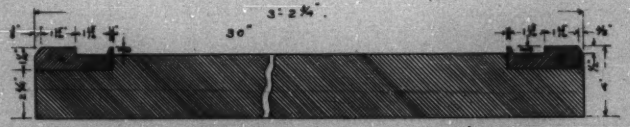
PLATE 6.—Pushing the rolled sheet from tray into the annealing oven. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

PLATE 7.—View of interior of works, showing portions of annealing ovens, glass furnaces, rolling platforms, etc. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

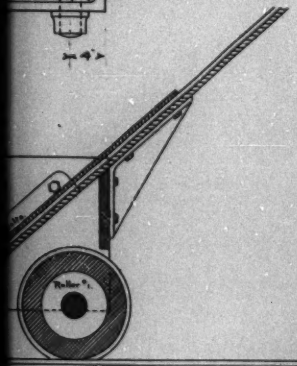

AMERICAN WIRE
GLASS MFG CO
Plate I. — 30" Glass Rolling Machine.
TACONY, PHILA. Dec. 9, 1893.
11"
11"
2'-8¾"
30"
1¾" Shaft
6½"
10½"
13½"
2'-0"
4½"
5'-6"
9'-0
18"
4'-10
4'-10
4'-10

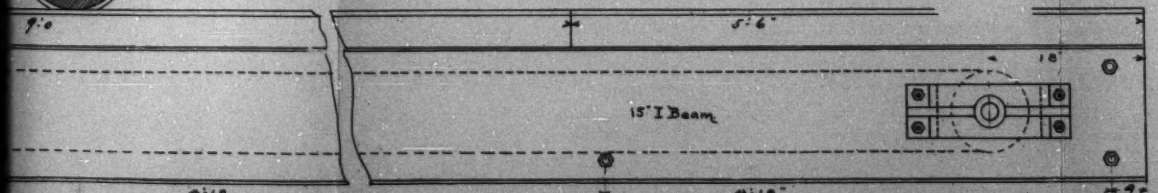
(Shuman)

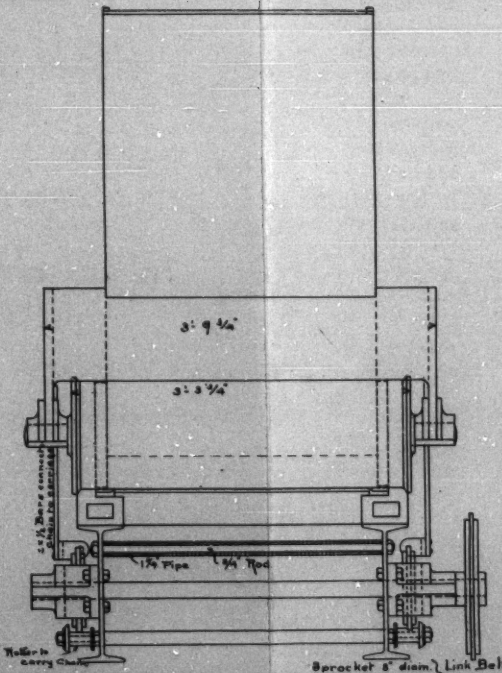




Section through Bed.
Wrot. Iron Strips AA are the size required for ⅞" Glass.







Sprocket 8" diam. } Link Belt
Sprocket 13½" diam. } No 78.

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that it may be heated from below by large gas jets, prior to beginning work. The table is made preferably of cast iron, and is provided on each side with ribs of sufficient height to allow for the rolling of the glass, and on the outer edges are rails upon which the rolls travel. On each side are rails, supporting the carriage before and after its travel. These rails are mounted in any suitable manner and are in line with the rails of the table.

The carriage is provided with four rolls, a front smoothing roll, a ribbed roll and two following smoothing rolls. It is moved across the table by power transmitted by means of a sprocket wheel and link belt. The front roll is intended to smooth out the molten glass after it is poured out upon the table and prepares it for the reception of the wire netting.

An inclined chute, for feeding the wire netting to the glass as this is spread by the front roll, is shown in connection with the carriage, arranged at the proper angle, and has a trigger, or other stop, at its lower end to detain the sheet of wire netting placed thereon until the proper time to discharge it upon the glass. The sheet of wire netting is preferably heated to the proper degree, so that it will not chill the glass when it is placed thereon. Directly back of the chute is a roll independently mounted in the carriage and having on its periphery a series of annular ribs (see plan) so arranged in reference to the table, as to press the wire netting into the molten glass. The ribs may be so arranged that although all the wire is incorporated in the molten glass some portions thereof will be pressed more deeply than others, thus corrugating the wire within the glass, if this be desired.

A smoothing roll directly behind the ribbed roll then passes over the glass and closes up the openings made by the ribbed roll and wire, completing the rolling of the glass. A second smoothing roll is preferably employed, as shown in the drawings, in order to correct the tendency of the rolled sheet, while still in the plastic state, to curl up over the first rear smoothing roll.

The finished glass is then removed and placed in an annealing furnace (see *Plates 5* and *6*). After the glass has

been annealed any glass or wire projecting over the edges of the sheet is cut off, after which the glass is ready for the market. The wire is preferably cut to the proper size prior to its application to the glass. The three smoothing rolls support the carriage, the ribbed roll being so mounted therein that it is free to rise or fall independently of the carriage. Thus, by raising this roll when the carriage is returning it will be clear of the glass. In order properly to handle the glass, the smoothing rolls are made hollow, and the heads are perforated to admit a gas pipe with jets for heating the rolls before beginning work. The rolls when thus brought to the proper temperature will not chill the glass during the process of rolling.

In operating the process a sufficient quantity of glass is poured upon the table at a point immediately in front of the first roll (*Plate 4*). As the carriage is moved forward, the roll smooths out the molten glass to the proper thickness, after which the wire netting is delivered upon the molten glass and pressed into it by the following ribbed roll. The next following smoothing roll closes the openings and corrugations made by the netting and ribbed roll. By this means a sheet of glass is produced with strips of wire, or a sheet of wire netting embedded therein. By having at certain distances, a series of annular grooves upon the ribbed roll, it is possible to corrugate the wire within the sheet. The heated wire being pliable, it will yield only at the points where it receives pressure, and may, accordingly, be made to follow a waving, or any other desired, course in the sheet, as the outline of the periphery of the ribbed roll shall determine. Thus the wire is, so to speak, woven within the glass in such manner as to tie both wire and glass together.

The glass after it has been rolled is carefully annealed in a furnace of the usual construction (*Plate 6*). The wire embedded in the glass not only strengthens the sheet, but also prevents the particles of glass from breaking entirely away from the main sheet, while, on the other hand, the glass protects the wire against corrosion.

From the foregoing abstract, it will appear that the radically novel feature of Shuman's apparatus is the ribbed or

grooved roll, by which the wire netting is pressed to a predetermined depth into the glass whilst the sheet is being rolled, and, at the same time, is permanently fixed in position by the following smoothing rolls; and the scope of the process may be defined as rolling out a sheet of glass, pressing into it a metallic fabric, and finishing the sheet by pressure of a heavy roll or rolls, whereby the metallic fabric is permanently embedded therein; these steps constituting practically a single operation.

The pressure of the rolls in the later machines is about fifty pounds to the square inch; the distance from centre to centre of the ribs or grooves in the ribbed roll is one inch. It has been found that with grooves of this size, any wire mesh between one-fourth inch and three inches can readily be embedded. These sizes of mesh represent the extremes of the sizes employed. A smaller mesh would require a groove of different size.

The average temperature of the fused glass is about 3,000° F. It is stated that the glass may be rolled at about 2,200° F., although the higher temperature is evidently the better one.

The inventions of Mr. Shuman are in practical operation on an extensive scale at the works of the American Wire Glass Manufacturing Company, at Tacony, Philadelphia.

The works cover an area of one and one-half acres, and the plant at present consists of one main building, 300 x 100 feet, and two auxiliary buildings, each 20 x 150 feet. The glass melting plant is an eight-pot Siemens regenerative furnace of the latest design and capable of melting ten tons of glass per day. The fuel used is gaseous, furnished by three Wellman gas producers. There are twelve annealing ovens of the Belgian type for tempering the glass sheets immediately after the wire has been inserted, and to these the glass is carried in a tray. These annealing ovens are heated by the Aërated Fuel Company's system using crude petroleum.

The steam plant consists of one fifty horse-power Babcock and Willcox, and one fifty horse-power upright, boiler. All mixing and handling of glass is done by machinery.

There are three sizes of rolling machines at present installed; two, capable of rolling sheets up to 24 x 84 inches; two, capable of rolling up to 30 x 84, and one machine capable of producing sheets as large as 54 x 144 inches.

Machinery has been introduced for handling the product wherever it could advantageously be applied. Thus, all the waste material is removed by tramways, and all cars and wagons are loaded from overhead tracks. The waste ends and imperfect sheets are utilized by separating the glass from the wire by means of special bending rolls. The glass broken off is returned to the furnace and the wire, wherever practicable, utilized for other sheets. With the experience now gained in the operation of the plant, it is stated that the percentage of defective sheets made is so small that it does not enter as a factor in the cost of production.

The rapidity with which sheets are made varies with the thickness. With three-sixteenths inch, the time of rolling is eighteen seconds; with one-fourth inch, twenty-five seconds; with three-eighths inch and over, thirty-five seconds. The capacity of the plant is 5,000 square feet per day of all sizes, and it is stated that the demand for the product has been large enough to keep the works fully occupied.

With its present facilities, which, it has been stated, will be extended as the requirements of business demand, the company is now engaged in the manufacture of wired-glass sheets of any required dimensions up to 4 x 10 feet and from $\frac{3}{16}$ to 1 inch in thickness. It is manifest that there must be a limit beyond which it would not be prudent to increase the dimensions of sheets on account of their weight, and the risk of cracking in handling and transportation. The usual dimensions for skylight and roofing glass range from 10 x 20 to 30 x 84 inches. Sheets larger than 48 x 144 inches, therefore, will rarely be called for.

The objection that has been urged against the process because of the difficulty of cutting the sheets to desired dimensions is a real one, but to a great extent has been overcome. In the operation of cutting, the sheets are first scratched with the diamond, then broken across the cut,

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PLATE 8.—View of interior of works, showing operations of cutting and trimming. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

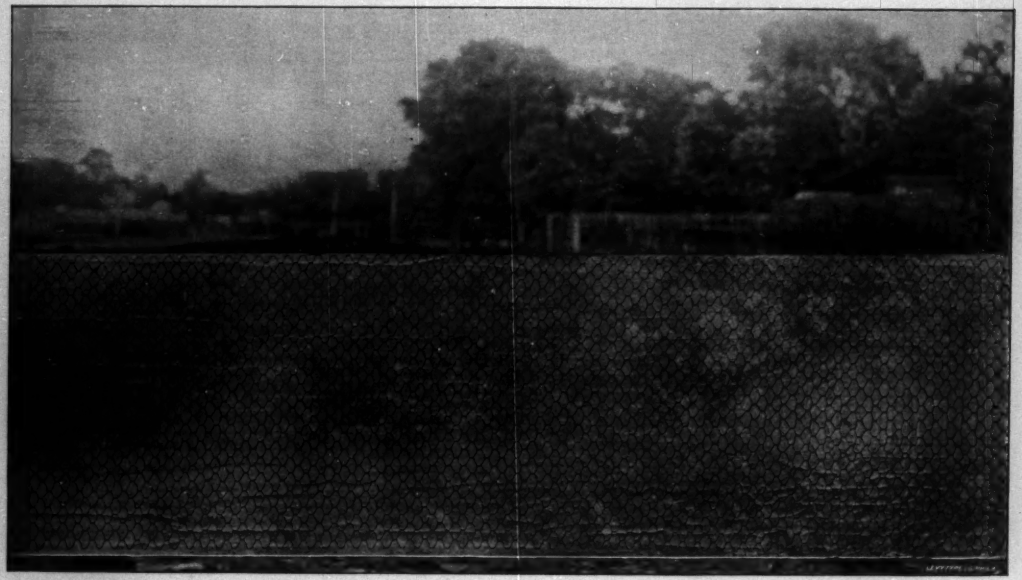

PLATE 9.—Showing the appearance of a finished sheet of wired glass. (American Wire Glass Manufacturing Company, Tacony, Philadelphia.)

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when the ductility of the embedded wire readily permits, by bending slightly to and fro, a sufficient separation of the edges of the cut to allow a thin-bladed saw to be inserted, by which the wires are cut through with comparative ease. In nearly all cases, however, the demands of the trade are for standard sizes, which require no cutting beyond that necessary to trim the edges.

The rolling machines, it should be explained, are adjustable, in length, breadth and thickness, up to their maximum range, to correspond with the dimensions of the sheets to be produced. Thus, on the same machine, wired-glass sheets of any thickness, width and length, within certain limits, may be produced, by adjusting the strips on the table for the regulation of the width, and the collars on the grooved roll for thickness: the length is regulated by that of the sheet of wire to be embedded and the quantity of glass poured upon the table.

By this adjustability of the rolling machines, it will be seen that the necessity of having a separate machine for each size of plate to be made is done away with, and that the problem of rolling sheets of any desired dimensions is practically solved.

Another point of interest which is worthy of notice, in connection with the operative features of the Shuman process, is the preliminary preparation of the wire for the production of the higher grades of wired glass. This consists in first removing the oil or grease from the wire by treatment with a cheap solvent (such as benzine), then passing the wire under a swiftly revolving roll, provided with bristles, and finally beneath flannel buffing wheels, whereby the wire is thoroughly cleansed and polished. For the best grades of wired glass, a specially annealed steel wire is used, which, after the cleansing treatment, presents a white and brilliant surface.

The following claims of merit, made on behalf of the new product, appear to be substantiated, viz: When used for the skylights in railway sheds, the much greater strength of wired glass permits the use of thinner and larger sheets, thus reducing the weights in the roof. It is hail-proof, and

proof against vibration. The copper wire netting which is now required beneath such skylights to protect persons below from injury by the accidental falling out of glass, may be dispensed with, thus saving not only the cost of the guard, but also the cost of renewing such netting when weakened by corrosion. The increased strength of wired glass will enable it to support with safety great weights of snow, which occasionally prove destructive to skylights of the ordinary kind; and, even should it become cracked by reason of rough usage or by accident, the tension of the wires will hold the fractured portions together, and the efficiency of the sheet will not be notably impaired.

Worthy of mention also is the fact that the common skylight guarded with wire tacked on beneath is so difficult to clean that this important item is practically neglected, with the result that the glass in time becomes greatly obscured by accumulations of soot and dirt.

It is probable that there would be much less likelihood of the occurrence of fatal or minor accidents caused by persons falling through skylights of wired glass when it is properly set in its frame; also, stones and heavy articles falling on such glass will often be arrested; and, on account of the time and trouble entailed in cutting through it with the diamond and severing the wires, it would interpose a much more serious obstacle to thieves, than the plain, unguarded glass. These qualities commend the new product for use in show windows where articles of value are exposed. It is proposed for windows in warehouses and stables, machine shops, railroad shops, and it is also suggested as advantageous for partitions in buildings. For deck, port and cabin lights in vessels, the same reasons should ensure its serviceability.

Finally, it is suggested that in the form of large sheets of extra thickness, strengthened by one or more enclosures of wire netting, and properly supported in an iron frame, wired glass would afford an advantageous substitute for the round bull's eye and other small patterns at present largely used for pavement and vault lights. The wired glass could not only be made sufficiently strong for such service, but

would also admit much more light per square foot of area than the forms of lights in common use.

These claims appear to be well founded.

The members of the committee of investigation, having had the opportunity of examining this invention in the course of its practical development on the commercial scale at the Tacony Works, are fully satisfied that the mechanical elements of the problem have been admirably worked out; that the present mode of manufacture is simple, efficient and rapid; and that the quality of the product is good. In conclusion, they find that the process and machine of Mr. Shuman, not only represent a marked advance upon all previous efforts in the class of inventions to which they relate, but also that they meet for the first time in this branch of the arts, the requirements of a practically operative method and means of manufacture.

For the reasons herein stated, and because of the undoubted advantages of wired glass for those uses for which it is adapted, the Institute recommends the award to the inventor, Frank Shuman, of the John Scott Legacy Premium and Medal, for his machine and process for producing wired glass.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

Approved, November 1, 1893.

H. R. HEYL,
Chairman of the Committee on Science and the Arts.

THE MANCHESTER SHIP CANAL AND ITS MORAL.*

BY PROF. LEWIS M. HAUPT, C.E.

[*A paper read before the Franklin Institute, December 20, 1893.*]

The corporation of Manchester, England, has just completed a ship canal, thirty-five and one-half miles in length, at a cost of $75,000,000. It was officially opened on the seventh of this month (December), after about six years of work, and it has justly engaged the attention of the engineering and commercial world as to its *raison d'être*.

The justification for this expensive structure arose from the physical and trade conditions of the locality which were believed to be injuriously affecting the manufactured products of the interior towns in the west of England, and restricting their markets by the high tolls required to reach the world's highway, the ocean.

This canal, therefore, unlike many others, was not built to reduce distance so much as to reduce rates, by bringing the ocean into direct competition with the railroads and the large canals already existing between Liverpool and Manchester. It furnishes a striking illustration of what an enterprising English manufacturing town will do to protect itself from injurious competition. The money contributed to this work was a *revenue for protection* against the excessive harbor dues of Liverpool, the cost of extra handling and the heavy railway charges.

Manchester evidently has invested a very large sum to escape the discriminations of Liverpool and secure the privilege of fixing her own port charges. The interest on this capital at four per cent. is $3,000,000, and it is believed to be a good investment for there are over 40,000 shareholders, thus evincing the great confidence of the public in

* Much of the information stated in this paper is derived from the report of Thos. Monro, C.E., to the Canadian Government.

the enterprise. It is estimated that the revenue from the 4,500,000 tons of prospective traffic will pay four per cent. on the investment. This would make the charge about sixty-six cents per ton—for both transit and storage—a very low rate on this comparatively limited tonnage. This does not include the cost of maintenance and operation but only interest. A better idea of the financial problem may be obtained by taking any article of the raw material and comparing the cost to Manchester via Liverpool, with that via the canal. Thus, cotton per ton is taxed as follows:

	s.	*d.*
Dock and town dues,	3	0
Master porterage,	1	3
Quay attendance,	1	0
Carting to rail,	1	3
Railroad or canal freight,	7	2
Total,	13	8

Whereas, by ship canal, we have:

	s.	*d.*	
Canal tolls,	4	3	= $1 06
Landing charges,	1	0	
Wharfage charges,	1	9	
Total,	7	0	

or about fifty per cent. less. The saving on one ton of cotton being $1.66. On sugar, the Liverpool charges are $4.47 per ton. On tea, the Liverpool charges are $4.54 per ton. The saving on sugar is $2.81 and on tea $2.40.

The manufactures of Manchester and vicinity would, therefore, save over fifty per cent. on the cost of transportation of these articles for this distance of thirty-five and one-half miles. The saving on wool is $2.16; on bacon, $2.10; on canned meats, $2.35; on wheat, $1.77; on petroleum, $2.12; on tallows, $1.91; on iron ore, $1.02, and on timber, $1.16. If there were no economies effected by this canal it would never have been built.

These, then, are a few of the reasons for the construction of this canal in the face of a bitter, organized and wealthy opposition and of unusual physical difficulties.

THE OPPOSITION.

As might have been expected, for it is incidental to all great works, this enterprise was strenuously opposed from its inception, both by the Dock Board and Corporation of Liverpool, and the various railway companies interested. About $750,000 were spent by its promoters in securing the necessary legislation. Its construction affords another proof of the fact that no railway can compete with a large canal in the cheap carriage of low grade freights.

It is stated that the famous Bridgewater Canal (which this one intersects) and on which barges of only fifty tons capacity are used, carries 60,000 tons of traffic per mile per annum, whilst the average of the railways of England is only 17,000 or less than one-third. It pays a larger dividend also than any railway in the country and has recently been bought by the Manchester Ship Canal Company, as a feeder, at a cost of $8,750,000.

The Leeds and Liverpool Canal, which is still independent of railroad control, pays an average dividend of over eighteen per cent. while the income from the Bridgewater Canal is said to be thirty-four per cent. on the above cost.

CONSTRUCTION.

The work was commenced November 11, 1887, by Mr. Thomas A. Walker, contractor, who expected to complete it in three years for a sum not to exceed $28,750,000 and $4,014,680 for land damages, but his untimely death, coupled with strikes, storms and the delays incidental to corporate management, conspired to postpone its completion and increase its cost.

On the fourth of February, 1891, it was found that the funds were practically exhausted and an appeal was made to the corporation of Manchester for advances, was promptly and cordially responded to, and the work was continued by the Directors. Thus this enormous work, involving 46,000,000 cubic yards of excavation and many expensive auxiliary works, to provide for the maintenance of existing traffic, was completed in six years, at a cost of about $2,000,000 per mile.

Beginning at the lower end, at Eastham, six miles above Liverpool in the Mersey, there are three locks placed side by side of different sizes to facilitate traffic. No. 1 is 600 x 80; No. 2 is 350 x 50, and No. 3 is 150 x 30, all having a lift of 9 feet 6 inches. This admits vessels to the reach extending through and beyond the estuary of the Mersey to Latchford, twenty-one miles distant. Here a second lift of 16 feet 6 inches is made by two locks abreast, No. 1 being 600 x 65 feet in size, and No. 2, 350 x 45. Thence it is seven and one-half miles to a third lift of sixteen feet at Irlam, where are found two more locks of the same dimensions as above. Two miles further brings us to the Barton locks of fifteen feet rise; otherwise, a duplicate of the preceding. Thence it is three and one-half miles to the Mode Wheel lift of thirteen feet with similar lockage and thence one and three-fourths miles to the landings at Manchester. This last reach constitutes the harbor and docks.

In addition to these eleven locks there are extensive quays at Warrington and Manchester, numerous sluices to provide for the movements of tidal and storm water, various swing and high level bridges, and one canal turn-table, with various other works of lesser magnitude.

STATISTICS.

Canal trench, minimum (120 x 26) (length miles),	35½
Total lift (feet),	70
Total excavation (cubic yards),	46,000,000
(of which 10,000,000 was sandstone rock.)	
Straight lines (miles),	20½
Curved (miles),	15
Minimum radius at Runcour (feet),	1,980
Number of railroad, high level, bridges (75 feet),	5
Total length of railway diversion (miles),	11¼
Road bridges, high level (75 feet),	2
Road bridges, swing (120 feet span),	6
Aqueduct bridges, swing, at Barton (290 feet span),	1
Area of Manchester docks (water acres),	114
Area of Manchester docks, quay space (acres),	152
Length of Manchester quay walls (miles),	5¼
Warrington docks (acres),	23

At Partington, canal widened and hydraulic coal tips introduced.

STATISTICS—*Continued.*

Time of transit including lockage (hours),	10
Number of bricks required,	70,000,000
Number of yards of concrete,	1,250,000
Number of yards of brick work,	175,000
Number of yards of masonry,	220,000
Steam excavators employed,	100
Locomotives (in 1890),	173
Wagons and trucks (capacity, 4 cubic yards),	6,300
Miles of railway (standard gauge) (miles),	223

The rate of excavation varied from 750,000 to 150,000 cubic yards per month; 2,400 yards per day of ten hours have been removed by one dredge. The German machines would average 2,000 yards per day, and the English 700.

Number of steam cranes,	194
Number of portable and other steam engines,	182
Number of steam pumps,	209
Tons of coal consumed, per month,	10,000
Value of the plant owned by Mr. Walker,	$5,000,000
Average cost of earth excavation (cents),	30
Number of men and boys employed, about,	20,000

The hydraulic turn-table for carrying the Bridgewater Canal is a large iron caisson, 234 feet long, 25 feet wide and 6 feet deep, having the ends closed by movable gates. A similar pair of gates also close the ends of the canal so that when a ship is passing through the Manchester Canal, the Bridgewater Canal is cut in two, and a section of it swung around as in an ordinary turn-table.

When full of water it weighed 1,430 tons. It is supported on sixty-four conical rollers, each 2 feet 8 inches long, operated, as are all the swing bridges and lock gates, by hydraulic machinery.

PHYSICAL DIFFICULTIES.

From this general description it will be seen that the physical difficulties were of no mean order. A tide of about twenty-seven feet; a heavy embankment through the estuary of the Mersey; a lift of over seventy feet; cuttings exceeding sixty-six feet in depth, and in one instance an average depth of fifty-five feet extending for one and one-half miles;

the cutting of the main river and its tributaries at numerous points, and the maintenance of the drainage systems during construction; the building of siphons under the canal in soft clay below sea level; the maintenance of traffic on the railways, canals and highways; the damages by floods and land-slides, which several times filled large sections of the works with mud and water, and which, below the locks at Latchford, rose forty feet and inundated the works for miles; the building of numerous sluices and rivers; and the long haul to the waste banks all bear tribute to the zeal, energy and perseverance of the contractors and the promoters of this great economic project so happily completed.

THE MORAL.

The laws governing the movements of trade are the same throughout the world. Commerce, like other streams, seeks the line of least resistance, and that is the one involving least time and money between terminals. A line which embodies a saving of distance, time, risks and cost has therefore the essential elements of success to insure it, and a nation or people having such opportunities, and failing to improve them must expect to suffer in the race for commercial supremacy.

To apply the lesson to ourselves we have only to remember that up to the opening of the Erie Canal in 1826, Philadelphia enjoyed the proud distinction of being the first commercial city of the United States. This was due largely to the energy of one man, Stephen Girard, whose benefactions still bless the community.

To-day, the waterways that formerly contributed so largely to our commercial and industrial growth, are almost abandoned, and we find ourselves over 100 miles from the highway of commerce, with but one circuitous avenue to reach it.

Like the tides our commerce must now ebb and flow through the Delaware capes, but it is a simple, cheap and economic physical problem to cause a continuous current past our doors, and to divert the track of the coastwise and

much of the foreign commerce from the outer dangerous passage to the inner safe and productive one by a ship canal across the girdle of New Jersey, and another across the neck of the Delaware—Maryland peninsula. If there were need for the Manchester Canal built by a corporation at the great cost of $75,000,000, and in the face of serious physical difficulties and vested interests, certain it is that there is far more reason for the enlargement of the Atlantic coast canals, under much more favorable conditions, at much less cost, and with a far greater tonnage in sight.

As the engineering and physical features of these projects have hitherto been presented to the Institute, I will only recapitulate that the line across New Jersey would be thirty-three miles long, having six locks with a summit level fifty feet above tide; the highest point on the divide being but seventy-six feet above tide or twenty-six above the summit level, while the drainage basin for its supply covers over 300 square miles.

If made large enough to carry the largest battleships or cruisers, its cost would probably not exceed $25,000,000.

In this connection it may be well to note that our defensive naval armament has cost the country over $65,000,000 in the last ten years and $12,000,000 more are appropriated, but unexpended.

The construction of these two canal links, which are essential to the successful use of this magnificent naval equipment, at a total cost of (say) $32,000,000, or less than one-half that of the vessels, will quadruple their efficiency by giving them control of the strategic lines of defence along the coast.

To quadruple the effective force of our navy at one-half its cost is a proposition which must demand consideration as an economic problem.

Again, from the humane standpoint, the necessity for this work asserts itself; for during the past fiscal year between Massachusetts and North Carolina there have been 214 wrecks, of which fifty-nine were total losses. The value of the property wholly destroyed was $1,146,395, or twenty-nine per cent. of the value risked. Of the 1,404 lives risked

only twenty-four were lost and most of them in the Fourth District, or on the coast of New Jersey.

This total loss for one year in this stretch of coast, if capitalized at four per cent., would represent $28,659,875, or a sum almost sufficient to canalize this entire route for deep draught vessels. Will any one say that it is not wiser to spend this money in saving life and avoiding the risks than in permitting it to be buried in the depths of the sea?

There are many other reasons—political, social. commercial and financial—why this work should be inaugurated, but I must refrain from lack of time. The project is old, dating back to 1812, but the times were immature and the machinery not available. Now they seem to be ripe, but still the canals await the "Touch of a vanished hand and the sound of a voice that is still."

The Executive Departments do not move because Congress is indifferent and Congressmen are inert because their constituents are not awake to the importance of the measure. The citizens do not urge it because there has been no concerted action to direct public attention to its importance and crystallize the movement, but when this shall have been done by such instrumentalities as your learned societies—the Franklin Institute, the American Philosophical Society, the National Board of Trade, the Trades League, the various engineering societies, commercial clubs, trade associations and kindred organizations—then like the familiar rhyme in Mother Goose, "When the mouse begins to gnaw the rope," the whole machinery will be set in motion, resolutions and petitions will flow into Congress; Congress will make the necessary appropriations; the Executive Departments will make the surveys and under the continuous contract system the canals will soon become an accomplished fact, and the world will wonder why it was not done long before.

Would it not be in accord with the honorable record of this distinguished organization if the Franklin Institute would press the button, connecting with the wires to Washington and start the machinery?

SLAG CEMENT EXPERIMENTS.

By R. W. Mahon.

[*Read by title at the meeting of the Chemical Section, October 17, 1893.*]

The manufacture of slag cement abroad has become a considerable industry, works having been established in a number of European countries. Probably the greatest development has been reached in Germany. In 1892, it was stated in a communication to the Architectural Association of Berlin, that there were then, in that country, ten slag cement factories with an annual production of 600,000 tons.

The blast furnace slags used in the following experiments were complex basic silicates of lime, alumina and magnesia, with a little ferrous oxide and alkali, and containing a small percentage of sulphide of lime. Furnace slag is somewhat cementatious; this property increasing with the contained lime. The cementing value of slag is greatly increased and hydraulic properties imparted to it by running it molten into water. This operation granulates the slag, but except for the possible elimination of a minute quantity of sulphur as sulphuretted hydrogen, leaves its chemical composition unchanged. Some change has, however, taken place in the molecule, to account for which various explanations have been offered. Thus it has been advanced that the change is analogous to that which sulphur undergoes when fused and quenched; an altered molecular condition being preserved.

Le Chatelier has suggested and presented calorimetric experiments in confirmation, that granulated slag contains the whole of the energy which appears as heat if the same slag be allowed to crystallize instead of being granulated; and hence that its atoms have greater power of combination. Whatever the change may be, the granulated slag, it is certain, possesses new properties, and can unite with calcium hydrate in certain proportions, when water is added, forming in the case of some slags a valuable cement.

Some time since the Maryland Steel Company entrusted the writer with an investigation of the slag from their blast furnaces, to determine its value for cement making. The experiments here recorded are laboratory experiments and of a preliminary character, preliminary to further laboratory experiments, and also to experiments on the manufacturing scale.

Attention has been here given, first to determine whether it were possible from these slags to make cement at all or not. This point having been decided in the affirmative, it was next sought to determine the range of slag available.

This company uses Mediterranean ores, and an ore mined in the island of Cuba. Their limestone comes from a point near the city of Baltimore. It is possible to divide this stone into two varieties: one containing a low percentage of magnesia, and one a higher percentage. It would be quite possible to reject the high magnesia stone at the quarries. This might prove useful in two ways, besides lowering the magnesia, and so increasing the safety of the cement, it would raise the percentage of lime. It seems probable that slag containing more lime, replacing magnesia, would furnish cements of greater strength. This limestone when in rather large crystals, either compact or loosely coherent, and of various colors and appearance, as white, blue, milky, etc., is invariably low in magnesia. Whereas the compact variety in small crystals and of various colors is invariably high in magnesia. Thus a series of magnesia determinations in these two varieties resulted as follows:

MAGNESIA PERCENTAGES.

Large Crystalline Variety.	*Compact Variety Composed of Small Crystals.*
2·48	13·44
0·57	17·55
1·44	14·66
trace	16·16
trace	17·58
0·90	13·15
1·19	
trace	

TABLE OF THE SLAGS USED.

Slag.	Silica. SiO_2.	Alumina. Al_2O_3.	Iron. Fe.	Lime. CaO.	Magnesia. MgO.	Sulphur. S.
1	35·00	11·27	0·51	46·40	4·68	1·23
2	34·10	14·69	0·71	44·10	3·60	1·76
3	33·80	15·19	0·71	44·70	—	2·21
4	33·50	15·81	0·92	43·36	4·25	2·48
5	33·30	13·12	0·41	49·00	4·97	—
6	32·50	17·80	0·10	46·00	2·81	2·54
7	32·50	15·92	0·41	47·20	—	2·24
8	32·00	19·20	0·10	45·50	2·16	2·30
9	32·00	12·19	0·92	46·50	5·76	2·07
10	31·80	14·77	0·51	45·90	4·50	2·23
11	31·00	18·80	0·10	43·90	2·70	2·16
12	31·00	17·51	0·20	45·00	3·24	—
13	30·00	17·00	0·10	47·50	—	2·38
14	29·90	16·94	0·81	45·00	2·52	2·33
15	29·10	15·70	0·10	48·80	4·03	2·31
16	28·68	15·08	1·00	47·20	3·96	2·46
17	25·30	22·10	0·10	48·00	3·28	2·63
A	30·62	16·94	0·38	46·38	3·71	—

A is composed of equal parts of Nos. 6, 10, 12, 15 and 16. Each slag was granulated by running it molten into water, dried, ground on an iron plate, and sieved through an hundred mesh sieve. A series of cements was prepared from each sifted slag above described, by grinding it with slaked lime, in several different proportions. The slaked lime used was prepared in the following manner: Lime was slaked in a covered vessel by heating with more than twice the theoretical quantity of water required to hydrate it. After slaking it was removed, and allowed to dry spread out exposed to the air. When dry it was ground, and was then ready for use.

	Water. H_2O.	*Carbonic Acid.* CO_2.	*Silica.* SiO_2.	*Alumina.* Al_2O_3.	*Ferric Oxide.* Fe_2O_3.	*Lime* CaO.	*Magnesia.* MgO.
The slaked lime, . .	19·75	6·84	5·08	1·38	0·22	61·44	2 64

The following table contains a record of the tensile strength of test pieces of neat cement prepared from the slag cements, and from a number of bought cements for comparison. The bought cements are a German-Portland of the best quality designated German; an English-Portland of the best quality designated English; two domestic natural rock cements designated American Nos. 1 and 2. The first column of each set of three gives the cements, the second the tensile strength of the test pieces of neat cement expressed in pounds per square inch, the third the condi-

tions in which the test pieces were kept and the time before testing. Those test pieces of neat cement which were immersed had always hardened sufficiently for that treatment in one day, and usually in part of one day; except those which were made from three slags, viz: Nos. 2, 4 and 6, from No. 2 most markedly.

Meaning of abbreviations used in the table:

w.—water; m. a.—moist air; d. a —dry air; sl. l.—slaked lime.

These tests indicate that the best slags for cement making are low in silica and high in lime and alumina. Slags containing

	Per Cent.
Silica,	30 00 or less.
Lime,	47·50 " more.
Alumina,	17·00 " "

have given the best results. The best cements were made with slags Nos. 13 and 17. As the silica increases, and the lime and alumina decrease, the cementing properties of the slag diminish. Thus the cements made from slag No. 2 were inferior.

The principal table contains the tensile strength of a number of slags granulated, dried, ground and sieved, but without the addition of slaked lime. This material hardens very slowly and is of a sandy character. The test pieces can only be removed from the moulds after hardening for several days. In the case of No. 17 slag after twenty-eight days in moist air, the test piece was a hard mass, but still slightly sandy on the outside, and possessing a tensile strength of 235 pounds per square inch.

The principal table contains examples of cements made with the same slags, granulated and not granulated, and shows the value of granulation for imparting cementing properties.

Tensile Strength in Pounds per Square Inch.

100 Mesh.	*150 Mesh.*
196	177
158	235
160	185
190	235

Conclusive experiments on the value of finer grinding could not be made with the simple appliances at hand.

Cement.	Tensile Strength.	Days in
German, ...	38	m. a. 1
	103	m. a. 3
	310	m. a. 6
	355	m. a. 6
	403	m. a. 28
	325	d. a. 28
	433	w. 28
English, ...	118	m. a. 1
	273	m. a. 6
	333	m. a. 28
	266	d. a. 28
	168	d. a. 28
	235	d. a. 28
	333	w. 28
American No. 1, .	45	m. a. 1
	72	m. a. 6
	109	m. a. 28
	88	d. a. 28
	79	w. 28
American No. 2, .	99	m. a. 1
	182	m. a. 6
	283	m. a. 25
	380	d. a. 25
	180	w. 25
Slag No. 4, . . 400 Sl. l., ... 60	170	m. a. 28
	60	d. a. 28
	136	w. 28
Slag No. 4, . . 100 Sl. l., ... 70	106	d. a. 28
	131	w. 28
Slag No. 6, . . 100 Sl. l., ...	Broke in	removing.
Slag No. 6, . . 100 Sl. l., ... 10	185	m. a. 28
	140	d. a. 28
	220	w. 28
Slag No. 6, . . 100 Sl. l., ... 20	176	m. a. 28
	230	d. a. 28
	240	w. 28
Slag No. 6, . . 100 Sl. l., ... 30	193	m. a. 28
	250	d. a. 28
	196	w. 28
Slag No. 6, . 100 *Sl. l., ... 30	177	w. 28
Slag No. 6, . . 100 Sl. l., ... 40	186	m. a. 28
	192	d. a. 28
	240	w. 28
Slag No. 6, . . 100 Sl. l., ... 50	126	m. a. 28

Cement.	Tensile Strength.	Days in
Slag No. 2, . . 100 Sl. l., ... 30	40	d. a. 28
	68	w. 28
Slag No. 2, . . 100 Sl. l., ... 35	166	m. a. 28
	75	d. a. 28
Slag No. 2, . . 100 Sl. l., ... 40	18	m. a. 28
	36	w. 28
Slag No. 2, . . 100 Sl. l., ... 45	14	d. a. 28
Slag No. 2, . . 100 Sl. l., ... 50	56	m. a. 28
	67	w. 28
Slag No. 2, . . 100 Sl. l., ... 55	125	m. a. 28
	84	w. 28
Slag No. 2, . . 100 Sl. l., ... 60	64	w. 28
Slag No. 2, . . 100 Sl. l., ... 65	104	m. a. 28
	91	w. 28
Slag No. 2, . . 100 Sl. l., ... 70	Went to pieces in water.	
Slag No. 2, . . 100 Sl. l., ... 75	Went to pieces in water.	
Slag No. 3, . . 100 Sl. l., ... 10	130	m. a. 25
	134	d. a. 28
	205	w. 28
Slag No. 3, . . 100 Sl. l., ... 30	210	m. a. 28
	225	d. a. 28
	250	w. 28
Slag No. 6, . . 200 Sl. l., ... 70	92	m. a. 28
	150	d. a. 28
	160	w. 28
Slag No. 7, . . 200 Sl. l., ...	Broke in	removing.
Slag No. 7, . . 200 Sl. l., ... 10	150	m. a. 28
	207	d. a. 28
	219	w. 28
Slag No. 7, . . 200 Sl. l., ... 20	77	m. a. 28
Slag No. 7, . . 200 Sl. l., ... 30	94	m. a. 28
	50	d. a. 28
	32	w. 28
Slag No. 7, . . 100 Sl. l., ... 40	115	m. a. 28
	240	d. a. 28
	245	w. 28
Slag No. 7, . . 100 *Sl. l., ... 40	185	m. a. 28
Slag No. 7, . 100 *Sl. l., ... 50	131	m. a. 28
Slag No. 7, . . 100 Sl. l., ... 60	240	m. a. 28
	150	d. a. 28
	190	w. 28
Slag No. 7, . . 200 Sl. l., ... 70	140	m. a. 28

Cement.	Tensile Strength.	Days in
Slag No. 3, . . 100 Sl. l., ... 40	240	m. a. 28
	193	d. a. 28
	238	w. 28
Slag No. 3, . . 100 Sl. l., ... 50	122	d. a. 28
	190	w. 28
Slag No. 3, . . 100 *Sl. l., ... 50	186	d. a. 28
	235	w. 28
Slag No. 4, . . 200 Sl. l., ... 30	158	m. a. 28
	59	d. a. 28
	103	w. 28
Slag No. 4, . . 100 Sl. l., ... 35	103	m. a. 28
	52	w. 28
Slag No. 4, . . 100 Sl. l., ... 40	158	m. a. 28
	104	w. 28
Slag No. 4, . . 100 Sl. l., ... 45	161	m. a. 28
	36	d. a. 28
	164	w. 28
Slag No. 4, . . 100 Sl. l., ... 50	180	m. a. 28
	93	d. a. 28
	159	w. 28
Slag No. 4, . . 200 Sl. l., ... 55	38	d. a. 28
	154	w. 28
Slag No. 8, . . 100 Sl. l., ... 20	235	w. 28
Slag No. 8, . . 100 Sl. l., ... 30	125	m. a. 28
	250	d. a. 28
	215	w. 28
Slag No. 8, . . 100 Sl. l., ... 40	140	m. a. 28
	260	d. a. 28
	200	w. 28
Slag No. 8, . . 200 Sl. l., ... 50	158	m. a. 28
	265	w. 28
	235	d. a. 28
Slag No. 8, . . 100 *Sl. l., ... 50	235	m. a. 28
Slag No. 8, . . 100 Sl. l., ... 70	180	d. a. 28
	250	w. 28
Slag No. 8, . . 200 Sl. l., ... 100	146	w. 28
‡Slag No. 8, . 100 Sl. l., ...	Broke in	removing
‡Slag No. 8, . 100 Sl. l., ... 30	Broke in	removing.
‡Slag No. 8, . 200 ‡Sl. l., ... 40	13	m. a. 28
‡Slag No. 8, . 100 Sl. l., ... 50	Broke in	removing.
Slag No. 10, . 200 Sl. l., ... 30	95	m. a. 28
	94	w. 28

Cement.	Tensile Strength.	Days in
	235	d. a. 28
	240	w. 28
Slag No. 20, . 100 Sl. l., ... 40	98	d. a. 28
	130	w. 28
Slag No. 20, . 100 Sl. l., ... 45	208	m. a. 28
	91	w. 28
Slag No. 20, . 100 Sl. l., ... 50	88	d. a. 28
	130	w. 28
Slag No. 10, . 100 Sl. l., ... 52	163	m. a. 28
Slag No. 20, . 100 Sl. l., ... 54	162	m. a. 28
Slag No. 10, . 100 Sl. l., ... 55	168	m. a. 28
	144	w. 28
Slag No. 10, . 100 Sl. l., ... 56	145	m. a. 28
Slag No. 10, . 100 Sl. l., ... 58	150	m. a. 28
Slag No. 20, . 100 Sl. l., ... 60	72	d. a. 28
	217	w. 28
Slag No. 10, . 100 Sl. l., ... 65	152	m. a. 28
	225	w. 28
Slag No. 10, . 100 Sl. l., ... 70	82	d. a. 28
	122	w. 28
Slag No. 10, . 100 Sl. l., ... 75	145 126	m. a. 28 w. 28
Slag No. 13, . 100 Sl. l., ... 30	96	m. a. 1
	95	d. a. 1
	98	d. a. 1
	235	m. a. 28
	220	w. 28
Slag No. 15, . 100 Sl. l., ... 40	98	d. a. 1
	144	m. a. 26
	245	d. a. 28
	208	w. 28
Slag No. 15, . 100 Sl. l., ... 50	96	d. a. 1
	150	m. a. 26
	200	w. 28
Slag No. 15, . 100 Sl. l., ... 70	70	d. a. 1
	156	m. a. 26
	240	d. a. 28
	150	w. 28
Slag No. 15, . 100 Sl. l., ... 100	195	m. a. 28
	140	d. a. 28
	144	w. 28
Slag No. 16, . 100 Sl. l., ... 30	250	d. a. 24
	198	w. 24

Cement.	Tensile Strength.	Days in
Slag No. 8, . . 200 Sl. l., ...	223	m. a. 28
Slag No. 8, . . 200 Sl. l., ... 10	136 200	d. a. 28 w. 28
Slag No. 12, . 100 Sl. l., ...	Broke in	removing.
Slag No. 12, . 100 Sl. l., ... 20	144	m. a. 28
Slag No. 12, . 100 Sl. l., ... 30	166	m. a. 28
Slag No. 12, . 100 Sl. l., ... 40	152	m. a. 28
Slag No. 12, . 100 Sl. l., ... 50	146	m. a. 28
Slag No. 12, . 100 Sl. l., ... 70	146	m. a. 28
Slag No. 12, . 100 Sl. l., ... 20	113	m. a. 28
	122	d. a. 28
	160	w. 28
Slag No. 12, . 100 Sl. l., ... 30	115	m. a. 28
	30	d. a. 28
	140	w. 28
Slag No. 12, . 100 Sl. l., ... 40	163	m. a. 28
Slag No. 12, . 100 Sl. l., ... 50	182	m. a. 28
	192	w. 28
Slag No. 12, . 100 Sl. l., ... 70	70	d. a. 28
	148	m. a. 28
	13	d. a. 28
Slag No. 13, . 100 Sl. l., ...	Broke in	removing.
Slag No. 16, . 100 Sl. l., ... 35	200	m. a. 24
	180	w. 29
Slag No. 16, . 100 Sl. l., ... 40	106	m. a. 24
	120	w. 24
Slag No. 16, . 100 Sl. l., ... 45	124	m. a. 28
	98	w. 28
Slag No. 16, . 100 Sl. l., ... 50	174	d. a. 28
	106	w. 28
Slag No. 16, . 100 Sl. l., ... 55	140	m. a. 28
	106	w. 28
Slag No. 16, . 100 Sl. l., ... 60	97	d. a. 28
	105	w. 28
Slag No. 16, . 100 Sl. l., ... 65	122	m. a. 28
	93	w. 28
Slag No. 16, . 100 Sl. l., ... 70	108	d. a. 28
	104	w. 28
Slag No. 16, . 100 Sl. l., ... 75	97	d. a. 28
	88	w. 28
Slag No. 17, . 200 Sl. l., ...	235	m. a. 28
Slag No. 17, . 200 Sl. l., ... 10	168	m. a. 28
	200	w. 28

Cement.	Tensile Strength.	Days in
Slag No. 10, . 100 Sl. l., ... 33	107	m. a. 28
	108	w. 28
Slag No. 13, . 100 Sl. l., ... 10	184	m. a. 28
Slag No. 13, . 100 Sl. l., ... 15	198	m. a. 28
Slag No. 13, . 100 Sl. l., ... 20	215	m. a. 28
Slag No. 13, . 200 Sl. l., ... 25	353	m. a. 28
Slag No. 13, . 100 Sl. l., ... 30	220	m. a. 28
Slag No. 13, . 100 *Sl. l., ... 30	266	w. 28
Slag No. 13, . 100 Sl. l., ... 35	225	m. a. 28
Slag No. 15, . 100 Sl. l., ... 10	56	m. a. 1
	184	m. a. 28
	205	d. a. 28
	158	w. 28
Slag No. 15, . 200 Sl. l., ... 15	80	m. a. 1
	200	m. a. 28
	185	w. 28
Slag No. 15, . 200 Sl. l., ... 20	53	m. a. 1
	72	d. a. 1
	108	d. a. 1
	200	m. a. 26
	240	d. a. 28
	160	w. 28
Slag No. 17, . 100 Sl. l., ... 15	200	m. a. 28
Slag No. 17, . 100 Sl. l., ... 20	265	w. 23
Slag No. 17, . 100 Sl. l., ... 25	240	m. a. 28
	156	w. 28
Slag No. 17, . 200 Sl. l., ... 30	210	m. a. 28
	373	d. a. 28
	253	w. 28
Slag No. 17, . 100 Sl. l., ... 40	201	m. a. 28
	245	w. 28
Slag No. 17, . 100 Sl. l., ... 50	176	m. a. 28
	200	w. 28
Slag No. 17, . 200 Sl. l., ... 75	265	d. a. 28
	182	w. 28
Slag No. 17, . 200 ‡Sl. l., ...	49	m. a. 28
Slag No. 17, . 200 ‡Sl. l., ... 30	76	m. a. 28
Slag No. 17, . 200 ‡Sl. l., ... 40	50	m. a. 28
Slag A, ... 200 Sl. l., ... 20	186	m. a. 28
Slag A, ... 100 Sl. l., ... 30	192	m. a. 28
Slag A, ... 100 Sl. l., ... 40	175	m. a. 28
Slag A, ... 100 Sl. l., ... 50	113	m. a. 28
Slag A, ... 100 Sl. l., ... 70	122	m. a. 28

* 150 Mesh. † Sandy. ‡ Not granulated.

Four experiments of this kind are collected here, taken from the principal table.

FINENESS OF THE BOUGHT CEMENTS, USING 100 PARTS OF ORIGINAL CEMENT IN EACH CASE.

Cement.	100 Mesh.		150 Mesh.	
	Left on.	Passing.	Left on.	Passing.
German	20	80	30	70
English, ...	33	67	49	51
American No 1, ...	37	63	37	63
American No. 2, ...	24	76	60	40

Cementing two Bricks Together.—Pairs of bricks first saturated with water were cemented together with a mortar composed of cement one part and sand three parts, by weight. These were kept in the dry air of the laboratory for various periods, lying loosely, not with pressure upon them as in a wall. It was then attempted to tear them apart by hand. The only mortars failing to stand this test, showing want of power of adherence to a brick surface, after hardening in dry air, were those made from cements, from the poorer slags, with small proportion of slaked lime, when these were tested for short periods.

Although none of the bought cements show shrinkage in dry air, some of the slag cements undoubtedly have a tendency to shrink in dry air. These are the cements made from the poorer slags. In these experiments this shrinkage was noticed most markedly with cements made from No. 2 slag. On the other hand, the cements from the best slags show no shrinkage in dry air. Slag cements set slowly, and the cements from No. 2 slag have been found to be exceedingly slow setting.

Test pieces of the slag cements prepared in the course of these experiments, seem to reach their full strength slowly, and this applies especially to pieces immersed in water.

The hardness is satisfactory for cements from the best slags for pieces in dry or moist air. The test pieces hardened in water have not been entirely satisfactory in hardness, although frequently having a tensile strength of

200 to 250 pounds per square inch after twenty-eight days.

Possibly a lengthened period of time would give test pieces of satisfactory hardness in water.

COMPOSITION OF THE BOUGHT CEMENTS.

Cement.	Silica. SiO_2.	Alumina. Al_2O_3.	Iron. Fe.	Lime. CaO.	Magnesia. MgO.	Sulphur Trioxide. SO_3.
German, ...	21·72	6·73	2·43	63·80	0·75	1·37
English, ...	22·40	8·64	2·03	61·50	1·36	1·40
American No. 1, . .	20·50	7·61	1·53	49·20	2·52	1·10
American No. 2, . .	31·56	11·90	3·78	37·10	1·55	3·05

The best results thus far reached, could probably be much improved upon, with increased facilities in the following ways:

Hotter granulation.

Finer grinding.

Slaking under pressure.

More intimate incorporation of the sifted slag and slaked lime.

By using slags and slaked lime made from selected stone.

By using slags slightly higher in alumina.

SUMMARY.

Slags low in silica and high in lime and alumina are best suited for cement making.

Examples.—

Silica. SiO_2.	*Lime.* *CaO.*	*Alumina.* Al_2O_3.
25·30	48·00	20·10
30·00	47 50	17·00

The best cement made from such slags is prepared by the addition of about twenty-five parts of slaked lime to 100 parts of slag by weight.

Mortar made of one of cement to three of sand from such cement binds two bricks firmly together, even in the dry air of the laboratory. Test pieces of such mortar, hardened one day in air and twenty-seven days in water compare favorably with such mortar for good bought cements. Neat cement test pieces from the best slags show

no shrinkage in the moulds in dry air. These cements set slowly. Their hardness is satisfactory. By far the most complete set of comparisons made was the study of tensile strength at twenty-eight days, of neat cement test pieces, one square inch in cross-section, hardened in dry air, moist air and water, both for slag cements and bought cements.

Four examples, selected from the principal table of tensile strain after twenty-eight days follow.

They are the English Portland and the American natural rock No. 1; both in extensive use in this country, and the best two of the slag cements.

Cement.	Tensile Strain.	Kept in
English,	266	d. a.
	333	m. a.
	333	w.
American No. 1,	88	d. a.
	109	m. a.
	79	w.
Slag cement,	375	d. a.
	210	m. a.
	253	w.
Slag cement,	353	m. a.

Baltimore, Md., September, 1893.

EXAMINATION of SPRING WATERS in FAIRMOUNT PARK.

By Reuben Haines.

[*Read at the stated meeting of the Chemical Section, January 16, 1894.*]

I have recently made a partial examination of the numerous spring waters that exist within the limits of Fairmount Park, determining chiefly the chlorine and nitrates. Three shallow pump wells not situated close to dwelling houses are also included. In both the East and West Parks the series proceeds northwards from Girard Avenue. The results are stated in parts per 100,000.

EAST FAIRMOUNT PARK.

	Chlorine.	*Nitrogen in Nitrates.*
(1) Spring in stone pavilion, Fountain Green,	·480	·166
(2) Stone fountain spring west of No. 1, near railroad,	·425	·140
(3) Dip spring at roadside, close to bridle path,	·536	·280
(4) Pump well at Rockland, east side of drive,	·930	·330
(5) Dip spring, east of Ormiston,	1·030	·150
(6) Pump well, Edgley, on grass plot east side of drive,	·225	—
(7) Dip spring, south of Strawberry Mansion,	·380	·100
(8) Fountain on stone steps from Strawberry Mansion to the River Drive,	1·330	·500
(9) Fountain on River Drive at foot of steps from Strawberry Mansion,	1·265 1·350	— ·425

Nos. 1, 2, 3, 4, 6 and first sample of No. 9 were collected October 18, 1893.

Nos. 5, 7, 8 and second sample of No. 9 were collected November 27th.

A sample of No. 5 collected October 18th gave chlorine ·93 parts per 100,000.

WEST FAIRMOUNT PARK.

	Chlorine.	*Nitrogen in Nitrates.*
(10) Pump well, Children's Play-ground, east side of drive,	·33	·12
(11) Dip spring in ravine southeast of Memorial Hall,	2·61	·48
(12) Dip spring at head of same ravine, close to the turn of the drive,	·61	1·00
(13) Spring enclosed in stone work on the road from Memorial Hall to the River Drive and opposite to the railroad,	·76	·44
(14) Dip spring beneath Lansdowne Bridge, southeast of Horticultural Hall,	·86	·22
(15) Dip spring near garden plots, southwest of Horticultural Hall,	·43	—
(16) Fountain spring in pavilion at Belmont Mansion,	1·64	·40
(17) Dip spring near south side of path to the recently abandoned Belmont Station,	·73	·15

All these samples from the West Park were collected October 27, 1893.

SPRINGS ON THE WISSAHICKON DRIVE.

The series begins at the first spring above Hermit Lane Bridge and proceeds in order up the stream.

	Date of Collection.	*Chlorine.*	*Nitrogen in Nitrates.*
(18) First spring above Hermit Lane Bridge, . .	June 10	·85	·54
	June 29	·85	·62
	Oct. 12	·91	·80
(19) Second spring, close to No. 18, ...	June 10	·70	·90
	June 29	·70	·97
(20) New stone fountain below Rittenhouse Lane,	June 10	1·05	·80
	June 29	1·13	·87
	Oct. 9	1·26	1·34
	Oct. 12	1·23	1·40
(21) Old stone fountain at junction of Rittenhouse Lane, ...	June 10	·99	·75
	June 29	1·08	·80
	Oct. 9	1·13	1·20
(22) Spring 400 yards above Rittenhouse Lane, .	April 16	·16	·09
	June 10	·15	.08
	June 29	·22	·08
	July 23	·22	—
	July 30	·214	—
	Sept. 17	·183	—
	Oct. 9	·207	·10
(23) Spring nearly opposite "The Monastery," .	April 12	·53	·24
	June 29	·54	·30
(24) Spring between Allen Lane Bridge and Gorgas Lane, ...	April 12	·26	·18
	June 29	·29	.30
	July 23	·30	—
	July 30	·29	—
(25) Marble Fountain, three-fourths mile above Valley Green Hotel, ...	April 12	·25	·11
	June 29	.30	·13
	July 23	·27	—
	July 30	·30	—
(26) Small spring above tenth mile-stone, ...	April 12	·24	·30
(27) Spring below Thomas Mill Road, ...	June 29	·30	·50
(28) Spring below Bell's Mill Road, ...	April 12	·33	·27
	June 29	·34	·57

Great differences in quality of the springs are apparent from the foregoing results. While one should scarcely venture an opinion as to their potability from determinations

only of chlorine and nitrates, yet it may be said that of all these springs No. 22 is unquestionably the purest at the present time. This water yielded no free ammonia or nitrites, and less than ·0020 parts albuminoid ammonia per 100,000. It agrees closely in chemical quality with perfectly uncontaminated spring water from wood-covered hills in Chester County, Pa.

Nos. 18, 19, 20 and 21 are, without doubt, contaminated by house drainage, the results of analysis being confirmed by inspection; but at present this sewage enters the spring water in a thoroughly oxidized condition, as shown by very low free and albuminoid ammonia and absence of nitrites. No. 8 and No. 9 probably originate from one source close to Strawberry Mansion. The high chlorine in these and in No. 16 at Belmont Mansion may possibly be caused by contamination with merely the contents of ice cream freezers at the restaurants attached to these popular resorts. In some of the other springs the contamination may not be of very recent date. Two of the wells appear to be purer than most of the springs in the East and West Parks.

The above results, however, indicate the desirability of a thorough sanitary inspection, accompanied by analysis, of all those springs showing the higher amounts of chlorine, namely, about 0·60 parts per 100,000 and upwards. This precaution appears particularly advisable for the reason that some of these springs are used for drinking by large numbers of people frequenting the Park. All the determinations of chlorine given were corrected for excess of silver nitrate required for the volume of liquid titrated.

A REMARKABLE ARTESIAN WELL WATER.

By Reuben Haines.

[*Read at the stated meeting of the Chemical Section, January 16, 1894*]

Some time ago an artesian well water was sent me, the character of which was so unusual that it is thought a record of the analysis would be of interest.

The well was situated in southern Alabama, about 300 yards from the Mobile River. Its depth was 685 feet, and an iron tube extended to the bottom through the sands, gravels and clays of the Gulf coast deposits. It was of the true artesian type, the water rising to the height of fifty feet above the surface, while the surrounding land had an elevation of but ten feet above sea level.

Two samples were sent, one in January, the second in May of the same year. Analysis of the first sample gave the following results. The water was of a dark brown color when viewed in a liter flask, but was tolerably clear and deposited only a slight sediment.

	Parts in 100,000.
Free ammonia,	0·3200
Albuminoid ammonia,	0·0120
Nitrogen in nitrates,	0·137
Chlorine,	79·767
Total solid residue,	171·50
Reaction of water,	strongly alkaline.

The solid residue from 100 cubic centimeters blackened slightly on ignition, giving an odor of burnt vegetable matter.

A partial analysis of the mineral constituents gave in parts for 100,000:

SiO_2 and Al_2O_3	Fe_2O_3	CaO	SO_3
2·75	0·95	1·35	0·38

The second sample was received on the twenty-eighth of May, having been collected about a week previously. Of

this a complete analysis was made, with results as follows:

COLOR (observed in tube two feet long)—very dark coffee brown.
ODOR (heated to nearly 100° C.)—unpleasant, odor of damp rotten wood.
TASTE (warm)—disagreeable, stale, brackish alkaline with organic flavor.
TRANSPARENCY—almost clear, a small amount of whitish sediment.

The sample was thoroughly mixed before analysis.

	Parts in 100,000.
Free ammonia,	0·6900
Albuminoid ammonia,	0·0740
Oxygen consumed (Kubel),	1·0892
Nitrogen in nitrates,	0·040
Chlorine,	99·80
Total solid residue (dried at 120° C.),	206·00

The solid residue gave on ignition a burnt woody or peaty odor. An animal odor was not perceptible.

The test for nitrites with sulphanilic acid and naphthylamine acetate was applied with rather uncertain result, except that there was possibly present only a small amount.

Heisch's test with sugar produced no change in the appearance of the water, indicating probable absence of phosphates.

The water concentrated by evaporation was strongly alkaline.

The sediment was composed of whitish flakes of vegetable matter of an indeterminate character. Numerous ciliated Infusoria—chiefly Paramæcia—were observed in the collected sediment.

The albuminoid ammonia was quite rapidly evolved, the first distillate of fifty cubic centimeters containing nearly three-fourths of the whole amount, when the distillation was conducted at the usual rate of fifty cubic centimeters in eight to ten minutes.

The mineral ingredients were found in this sample to be:

	Parts in 100,000.	*Grains per U. S. Gallon.*
Lime,	1·50	·87
Magnesia,	·64	·37
Potash,	2·90	1·69
Soda,	102·72	59·91
Chlorine,	99·80	58·20
Sulphuric acid,	·103	·06
Silica, iron oxide and alumina,	·85	·49

These ingredients probably existed in the following combinations:

	Parts in 100,000.	*Grains per U. S. Gallon.*
Potassium sulphate,	·22	·13
Potassium chloride,	4·40	2·57
Sodium chloride,	161·19	94·00
Sodium carbonate,	29·33	17·10
Calcium carbonate,	2·68	1·56
Magnesium carbonate,	1·34	·78
Silica, iron oxide and alumina,	·85	·49
	200·01	116·63

From the above results it will be seen that about ninety-seven per cent. of the mineral ingredients consist of sodium and potassium chlorides and sodium carbonate, the latter forming nearly fifteen per cent. of the total mineral matter.

On acidifying and warming the water, the organic matter separated as a light-colored flocculent precipitate which redissolved on addition of caustic or carbonated alkali. Excess of sodium carbonate perceptibly intensified the color of the solution as compared with that of the water made only slightly alkaline.

The more remarkable features of this artesian well water which are here to be noted are the very high color, approximating that of water from pools in bogs and swamps, and the enormous amounts of ammonia and of organic matter. Deep well and artesian waters are usually colorless and particularly free from organic matter, on account of the vast amount of filtration to which they are generally subjected. In uncontaminated ground waters ammonia is usually absent or present only in traces, since the ammonia existing in rain water as well as that resulting from natural slow decay of vegetation is converted in the soil to nitrate, which is to a large extent withdrawn through absorption by living plants. Yet deep artesian well waters occasionally contain considerable ammonia, which the great depth of the well, and other circumstances, show has no connection with sewage pollution. In some instances it has been referred to coal deposits which always contain nitrogen.

An instance of the occurrence of large amounts of free

ammonia in two shallow wells which were uncontaminated with sewage is mentioned in the *Report of the Massachusetts State Board of Health on Water Supplies, 1890.* These were two tubular driven wells, respectively, 17 and 44 feet deep and sunk 16 feet and 28 feet below the water-table, situated at Provincetown, on the northern extremity of Cape Cod. The following is abstracted from the analyses published in the above *Report for 1890*, pp. 274–75, in parts per 100,000.

	No. 1.	*No. 2.*
Free ammonia,	0·0246	0·0614
Albuminoid ammonia unfiltered,	0·0230	0 0244
Albuminoid ammonia filtered,	0·0216	0·0198
Color (0 01 mgm. NH_3 nesslerized in 50 cc. = 1)	3·30	2·80

The first of these wells was situated near a cranberry bog. The free ammonia is attributed to the decaying bodies of fish buried deep in the sand which forms the narrow extremity of Cape Cod. The deep brown color of these well waters is ascribed to a peaty layer under the sand. (*Report Mass. Board of Health, 1892*, p. 329.)

Reference may be made here also to the filter-galley, situated on the shores of the reservoir of the Wayland Water Works, Mass., the water of which although free from any contamination with sewage, always contains considerable free ammonia, while the water of the reservoir contains very little. This is attributed to imperfect filtration of the vegetable matter in the reservoir and its partial decomposition in the ground itself which is associated with iron oxide and the development of the fungus Crenothrix. (*Report of 1890*, p. 778, and *Report of 1892*, p. 325.)

Ammonia in natural waters may arise not only from decomposing animal matter, but also from the slow decay of vegetable substances which, like leaves, grass, etc., contain nitrogen. If the supply of oxygen is deficient, the process of oxidation of the nitrogen is arrested in its earlier stages and but little nitrate or nitrite is formed, especially in the presence of large excess of organic matter. Deep well waters are usually deficient in oxygen.

It appears probable that the greater part of the dissolved organic matter in the artesian well water from Alabama

is derived from a submerged peat bog or swamp, several hundred feet below the surface, overlaid with the diluvial drift, called "Orange-sand" by Professor Hilgard, and the alluvium of this region.

Under ordinary conditions the dissolved peaty matter occurring in *surface waters*, such as many streams and ponds in Massachusetts, does not appear to be prone to decomposition with attendant formation of ammonia. Normal uncontaminated waters of this class possess, according to Dr. T. M. Drown, a remarkably permanent character. The dark colored water of the Acushnet River, the water supply of New Bedford, is described as an instance of this fact.

It does not seem probable that so excessive an amount of ammonia as occurs in the Alabama well can be referred to decomposition of the vegetable substance alone, and that a portion of it, at least, must be caused by decomposition of the organic remains of fish and other marine animals, which have been, perhaps, partially preserved from decay through the antiseptic properties of peat. A quantity of bones and shells mingled with sand is stated to have been thrown up by this well during the interval between the analysis of the two samples sent me, which appears to indicate, in connection with the greatly increased free and albuminoid ammonia in the second analysis, that the above inference may be correct. The rapid evolution of the albuminoid ammonia and the readiness of the water to undergo putrefactive changes while standing in the laboratory also accord with this view. The animal odor, which would have been expected on ignition of the total solid residue, may have been masked by the large amount of vegetable matter and chlorides. The presence of species of Paramæcium is also a presumptive evidence of the existence of animal matter, for although these animalcules are especially abundant in decomposing vegetable infusions, they are regarded, when found in ponds and shallow well waters, as indicating probable contamination with sewage or other effete animal matter, and from a sanitary standpoint are, therefore, to be viewed with strong suspicion. The development of these Infusoria was no doubt incident

to the exposure of the water in a tank before the sample was bottled for analysis.

The excessive amount of sodium chloride in this well water may be attributed to the probable existence of saliferous beds somewhere in the vicinity. It is stated that during the Civil War "salt was obtained in considerable quantities from beds in the southwestern part of the State (Alabama), but the working of these has ceased to be profitable." (*Encyclopædia Britannica, American Supplement*, vol. i, "Alabama.") From the results of analysis it is manifest that the water has no direct connection with the sea, for its mineral composition is totally unlike that of sea water. The pressure of the water at the mouth of the well is of itself sufficient evidence that the water has an altogether different origin.

THOUGHTS ON COSMICAL ELECTRICITY.

By Elihu Thomson.

[*A lecture delivered before the Electrical Section, December 19, 1893.*]

Having been requested to speak to the Electrical Section of the Institute on some subject, it occurred to me that I might take the opportunity to present a few thoughts in the nature of speculations on the electrical relations of the earth and the heavenly bodies.

Where we have no definite knowledge we are forced to speculation, and often scientific speculation points the way to further advances in our theories. While speculation is not science, science is often benefited by speculative ideas; speculation is the result of imagination, science of investigation.

We know but little as yet regarding the actual facts in the study of cosmical electricity. We do know, however, that there is every reason to believe in the existence of electrical disturbances in space, and either proceeding from or concentrated by the bodies in the solar system.

We have, indeed, much to learn, and the difficulty of learning is the greater as we are called upon, in this case, to apply known principles to conditions comparatively unknown and difficult of conception by our mental powers. As an illustration, I may mention the paradox of the canals of Mars. Of all the planets, Mars is the one which appears to be like the earth, and, therefore, is the one, the phenomena of whose surface, it would seem, should yield most readily to interpretation. But we are puzzled at the very outset. So, also, it must be with a subject such as I have chosen for my talk to-night.

It is known that as we leave the surface of the earth and rise in the air, there is an increase of positive potential with respect to ground, such that on the top of the Washington Monument it may be 3,000 to 4,000 volts, and on the Eiffel Tower as much as 10,000 volts. On high mountains similar high potential differences are found. If the increase were equal to 1,000 volts for each 100 feet on the average, it would equal, at twenty miles altitude, about 1,000,000 volts, and from this it might be inferred that the conducting vacuous layer of rarefied air at great altitudes would possess a very considerable positive potential with respect to ground.

But just here we are confronted with a difficulty. It is not clearly proven that a pure gas, rarefied or not, can receive and convey a charge—solid or liquefied particles in it might readily do so, but there are considerations which seem to negative any assumption that gas molecules can themselves be charged.

If we imagine a charged drop of water suspended in air and evaporating, it follows, that, unless the charge be carried off in the vapor, the potential of the drop would rise steadily as its surface diminished and would become infinite as the drop disappeared, unless the charge were dissipated before the complete drying up of the drop by dispersion of the drop itself, or conveyance of electricity by its vapor. The charge would certainly require to pass somewhere and might leave the air and vapor charged. However this may be, the vacuum outside of our atmosphere is probably per-

fect, and, therefore, a perfect insulator. The ether itself appears to be the best insulator, or most nearly perfect non-conductor of electricity.

It is customary to speak of a charged body—this metal ball insulated in air, for example—as a thing by itself, but we well know that its capacity to receive a charge depends on the thickness of the surrounding dielectric, or the nearness of other conducting surfaces, such as the walls of the room, the floor and ceiling and other objects about it. The insulated ball is none the less one of the coatings of a condenser, the capacity of which depends on the thickness of the dielectric layer separating it from those objects or surfaces which form virtually the other coating.

It is doubtful then if a single body, in unlimited space, would be able to receive a charge of electricity, and it follows that even very large bodies like the earth and stars, separated as they are from one another by immense distances, cannot have much capacity. A comparatively small amount of electricity would give a very high potential in such a case.

It becomes an interesting question, just here, whether the fact that a charge resides only on the surface of a charged sphere or conductor, is due to attraction of opposite charges of sphere and surrounding objects, or to repulsion of like charge in the sphere, or to both. A simple consideration will show, I think, that it is due to both causes, and that lines of electrostatic induction joining oppositely charged surfaces and traversing the dielectric between them, are like lines of magnetic force, in that they both tend to spread laterally and also to shorten their paths. Their actual course, as is the case with the lines of magnetic force, will be determined by the resulting balance between both tendencies. Thus in *Fig. 1*, if two opposed surfaces *A B* are charged relatively, and then the surfaces be extended laterally, as indicated by dotted lines, and the extensions be of receding character, as shown, the charge will distribute itself over the added surfaces by virtue of the lateral spreading of the lines, while in doing this the actual length of the lines is increased.

Now, returning to the case of the earth, its capacity as a body insulated in space could not be very great, and a moderate amount of electricity in coulombs would give it a high potential. Viewed in another way, however, the earth may possess a much greater charge, or amount, of electricity. The solid earth itself is a conductor, the dense air around it a good insulator and dielectric layer, the rarefied air above a quasi-conductor in the sense that it can at small potential differences distribute a charge or convey a current, and the ether outside is a perfect insulator.

The earth may then possess the character of a huge conductor, the outer coating being rarefied conducting air, the inner coating, the ground and water surface and the dielectric the dense air between. The outer layers may

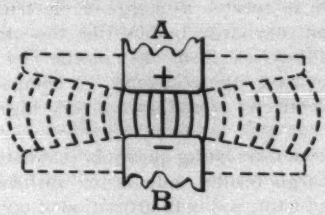

FIG. 1.

possess a potential, positive with respect to the earth's body, of, perhaps, as much as 1,000,000 volts.

Prof. H. A. Rowland has shown, however, that a moving charge is equivalent in magnetic effects to an electric current representing a similar transfer of electricity, and that a rotating charged air condenser produces that magnetic field which would be due to a current going in the direction of the moving changes on each plate. Applying this to the earth considered as a huge revolving condenser, *Fig. 2*, the dense air layer *A A A A* would become magnetized from pole to pole, and the velocity of the equatorial portion being so much greater than that of portions near the pole, would allow the magnetic lines to dip on each side of the equator in short-circuiting themselves through the solid earth *E*.

Moreover, the magnetic field so produced does actually correspond in direction of polarization with that which would be given when the outer coating *V V* is positive to the inner *E*, thus confirming so far the hypothesis which I have ventured to present to your consideration. It is merely a thought, and would need comparison of many data to give it a secure basis as a theory.

Any action which would disturb the charge of the con-

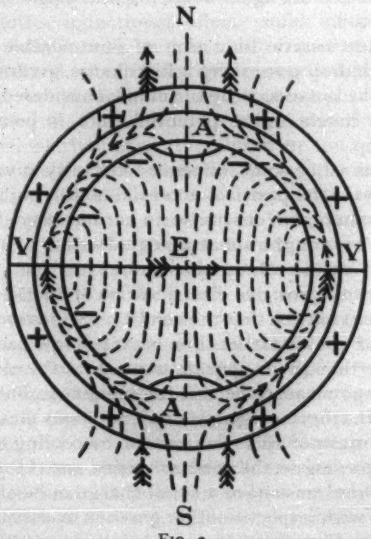

FIG. 2.

denser earth, would strongly affect the earth's magnetism and auroras especially would do so. They appear to represent a distribution of charge in the outer layers of the earth's atmosphere.

Assuming the earth to be a huge charged condenser, a thunder-storm might be brought about by a flow in the dense air dielectric, due to the presence of clouds of condensed vapor, extending to great altitudes. They may be

the auroral actions repeated in denser air, giving spark discharges, where in the aurora the diffused vacuum discharge only is seen.

The enormously high potentials exhibited in the thunderstorm may be secondary effects, due to coalescence of many minute drops of water charged to only moderate potentials, the reduction of surface raising the potential. It may in part be due also to evaporation of charged drops in some parts of the cloud, again reducing the surface and raising the potential.

The electrostatic induction of innumerable drops in a cloud, each drop possessing a like charge, gives virtually the effect of the possession by the cloud, considered as a whole, of a very much higher potential than is possessed by a single drop.

There must be some influence constantly at work to cause and maintain the positive potential of the higher layers of the atmosphere, for otherwise in various ways there would naturally be brought about an equalization of the charges of air and earth. Many theories have been proposed to account for the positive electrification of the air in its upper layers, and it may be that the condition is the result of a combination of causes rather than of any single cause. It is a legitimate thought, it appears to me, that the electrification may in large measure be due to influences outside of the earth itself. Let us assume a vast nebulous mass as having been the origin of the solar system by cooling and condensation, according to the nebular theory, and if for any reason that nebulous mass have a small charge or be at a potential difference with respect to other gaseous masses in space, the diminution of surface during shrinkage would gradually increase the potential of the charge, provided it could not escape through the surrounding ether. This charge would increase in potential until the finer particles on the outside of the mass were repelled outwards with a force equal to their centripetal tendency or gravity. A dispersion of such particles would ensue, and result in a fall of potential. The dispersion and accumulation of charges would occur periodically, while the hot mass of gas was shrinking and the par-

ticles sent off would be condensed vapors, liquid or solid, forming a charged cosmic dust proceeding in a radial direction from the central mass, just as the carbon sent out from a filament of an incandescent lamp leaves the filament radially after having condensed from vapor to solid carbon immediately at the surface of the filament, owing to the instant loss of the heat necessary to keep it vaporous.

Now the distance between the sun and a planet, such as the earth, is so great, that it is not probable that any considerable static—inductional effect could exist between them, even if they were at great differences of potential. On the other hand, electrified particles repelled periodically from the sun would reach the earth's atmosphere. It has been suggested that the coronal streams seen during total eclipses, particularly during the active or sun-spot period, may consist of electrified particles leaving the sun. If so, their lack of visibility, beyond a few diameters from the sun, would not forbid the assumption being entertained as a rational one, that the streams may pass outward indefinitely until they encounter some obstacle like the earth. But auroral displays on the earth are frequent only when the solar activity is greatest, when the coronal streams extend outwardly the farthest, and there appears to be a distinct connection between the presence of large spots on the sun's surface and auroral disturbances here.

Can we not consider that during an aurora the earth is passing through a coronal stream and developing, as it were, a secondary aurora, either by directly encountering in space the electrified particles from the sun, or by induction from streams of such particles near the earth's course?

Taking these thoughts in connection with the idea of the cause of the earth's magnetism presented above, it will be easy to understand why magnetic disturbances should be prominent during auroras. Taking also the fact that the sun is a charged body, and probably the planets also, it will be understood that some influence on the earth's condenser charge would exist, varying according to the positions relatively occupied by these bodies, and particularly of earth and sun. This in turn would give rise to magnetic variations,

such as the diurnal, annual and secular variations. It would account for the fact that the diurnal variations are greater when the earth is nearer the sun than when more remote.

My thought then, is, that the sun may be a charged body insulated in space, and, that owing either to a periodical accumulation of charge up to a certain critical potential, which would repel the outer particles into space and so relieve itself, or, to thermal disturbances occurring periodically during the cooling, the sun-spot period, or active period, recurs every eleven years, deforms the sun's outline, so far as the outer atmosphere is concerned, and raises the potential or the projecting parts to a degree to cause repulsion of particles; continuing until a certain discharge is effected, after which there is quiescence again.

During these actions the earth passes through, or near to, electrified streams and an aurora, or earth corona, is developed.

Concerning auroras, it would appear from observations of the great displays that the crown, or corona, seen in the zenith, is merely a view of bundles of streamers *on end*, and that the streamers in the north while nearly radial to the earth, are seen in perspective, rapidly changing their shapes and positions, while to the east and west are seen as comparatively stable but less defined streamers—an average view of great masses extending hundreds of miles and made up of innumerable changing streams of which the luminous effect is nearly steady. The grandest aurora which ever came under my personal observation was that of April, 1883, which reached its maximum between twelve and one o'clock. The whole horizon was in view as I was on top of a hill, and it is no exaggeration to say that the whole sky from north to south horizon and from east to west, was filled with auroral streams of wonderful coloring. The crown in the zenith was a marvellous display of changing light, changing positions, changing intensity and changing color. The streamers in the north were sharply defined like great bundles of luminous needles and seemed almost within reach. They changed rapidly, were remarkably brilliant and covered an angle from about 20° altitude

almost to the zenith. The stars, even of the first magnitude, could scarcely be seen, and although there was no moon, the time could easily be read on a watch, and the roofs of buildings, ten miles away, could easily be distinguished. I mention this aurora particularly because it showed in a most striking way the characteristics stated above, as indicating the radial position of the streamers. On no other theory could the zenith crown and streamers be seen simultaneously at places hundreds of miles east and west and many miles north and present substantially the same appearance.

It would appear that auroral displays are either much more rare in the southern hemisphere or absent altogether. Speaking on the subject with Dr. Gould, of Harvard University, he informed me that, although he had lived in Chili for fifteen years and was constantly on the watch for auroras, he never in that time saw a single display.

Now, if a discharge is taking place under critical conditions in a high vacuum, the relation of its path and direction to a magnetic field in the vacuum may determine the continuance or cause a stoppage of the discharge, according to the direction of magnetic polarization. Or, a stream of electrified particles may be deflected by a magnet, as shown in the well-known Crookes tubes. From this it might follow that the magnetism of the earth may be inhibitory to the discharge in the southern hemisphere and favorable to it in the northern, in which case the relatively greater frequency of the aurora *borealis* would be explained.

It has been found as a result of recent investigations that a negatively charged body will, if exposed to violet light, dissipate its charge to surrounding bodies, probably by sending off atoms, molecules or particles of its own substance negatively charged.

A positively electrified body placed in the neighborhood of a body maintained at a negative potential under violet light, is soon discharged by the negatively electrified particles coming to it from the negative body even when the positively charged body is not in the light. Whether this dissipation of negative charges would take place in the

ether itself, or in a very high vacuum, is, so far as I am now aware, not known. Evidently, however, such an action would have a very marked influence on the retention and distribution of charges on the earth.

If the sun's charge be positive and positively electrified particles are sent out in the coronal streams, it would be easy to understand that the outer earth charge might be kept up from the sun and that not only auroras, but thunderstorms also would be more frequent during periods of solar activity. Observations tend, I think, to show that such is the case.

Again, if the sun be a highly electrified body, might it not be possible that cometary masses may owe some of their illumination to redistribution of electricity as they approach towards and recede from the sun, or to encounter with electrified particles leaving the sun? Here, again, the radial direction of the comet's tail is suggestive, as are also the rapid changes which the comet undergoes.

And lastly, as a concluding thought, we may ask whether the phenomena of the sudden appearance of a star, which, after reaching great brilliancy, fades out in a few days or weeks, may not be referred to electrical causes, such as the equalization of charges on near approach of two bodies, attended as it must be with an enormous evolution of light, gradually fading away as the vapors cool after the discharge. Thus, some of the temporary stars may possibly be explained.

In conclusion, I beg to remind you what I have offered you here are only thoughts, not theories—which a careful comparison of all the facts may serve to confirm or to discredit. Objections may arise, but oftentimes what seems an insuperable objection disappears in the light of more complete knowledge and observation. It is true that the thoughts presented are not all new, and it is only the more gratifying when others may have arrived at similar guesses. Though generally busy with the practical side of electrical science, it is a source of pleasure sometimes to let one's thoughts have full play, even if the result be only a maze of speculation, some part of which may prove to be fallacious.

THE THEORY AND DESIGN OF THE CLOSED-COIL CONSTANT CURRENT DYNAMO.

BY HENRY S. CARHART.

[*A lecture delivered before the Electrical Section, December 26, 1893.*]

[*Concluded from p. 149.*]

The second method diminishes the overlap of the brushes as they are rocked forward. In the first place this has the effect of diminishing the time allowed for the reversal of the current, but it also diminishes the number of turns of wire in the coil or coils included between the two parts of each brush. The curtailed time interval increases the self-induction of each convolution of wire because it increases the rate of change of the current in the coil undergoing commutation; but this increase is counterbalanced by the diminution in the number of turns of wire short-circuited by the brush. Hence, the total self-induction during commutation remains not far from constant. When the brushes shift forward into a denser field, however, the diminution in the overlap decreases the number of turns of wire included between the pair of brushes composing either the positive or the negative, and so cuts down the total field induction in those coils during commutation to the amount required to suppress sparking. The overlap of the brushes must therefore be inversely as the induction in a coil under the brush in different parts of the field, for the presence of the pole of the armature at any point reduces the induction. This point is a complicated one and needs further experimental study.

But in the third class of machines the overlap of the brush is constant, and the field is not weakened by cutting out coils on small load. Neither are the pole faces cut away to produce uniform induction. Attention is given to the thickness of the pole pieces so as to avoid unnecessary crowding of the lines of force toward the central portions. It is also desirable to avoid thinning of the polar horns lest they become saturated. In the old Sperry machine, which

I have investigated quite carefully, each pole piece is cut quite in two. In fact, as is well known, the field has four cores. At the same time the horns or pole tips are rather blunt. But this machine shows the violent sparking when separately excited, when the brushes are far forward and the circuit through the armature is open. The induction round the armature is not uniform, but the sparking is small for any position of the brushes with the normal current. The brush bears on about three commutator segments. I refer to this machine as an illustration of the class, and not as a model of excellence. It is no longer built.

In this machine the induction to which a coil is subjected near the brush is not the same in different parts of the field, but diminishes as the brushes are rocked forward, the current being kept constant. With the exploring coil before described and the two extra brushes bearing on the insulated copper ring and the fibre collar with brass segment, respectively, the external circuit connecting the two small brushes was carried through a d'Arsonval galvanometer in shunt. The two extra brushes were attached to the two main brush holders, but were insulated therefrom. With the one making contact with the small brass segment two and then three commutator bars in advance of the upper main brush, the following deflections were obtained with the galvanometer from maximum to minimum load, the steps being about equal.

DEFLECTIONS.

Two Segments.	*Three Segments.*
26	63·5
24	56
22	49
20	41
18	34
16·5	32
13·5	
12·5	28
10·5	

The steps were not the same in the two series of observations. No trouble was found in obtaining a steady deflection of the galvanometer, the dynamo making about 1,200

revolutions per minute. The exploring coil was therefore subject to a diminishing induction near the brush as it moved forward with the brush toward the centre of the polar surfaces.

A similar series of experiments, made on an old Gramme machine of 3,000 or 4,000 watts capacity, built at the University of Michigan in 1876–77, gave a different result. The measurements were made by simply connecting a third brush to the upper brush holder and measuring the potential difference between it and the main brush in different parts of the field. The actual induction to which the armature wire is subjected in different parts of the field and at the same distance of two commutator bars from the main brush is thus measured.

The following table contains one series of observations:

Number of Observations.	Current in Ampères.	Potential Difference between Main Brushes.	Potential Difference between Main and Third Brush.
1	9'5	191	4'9
2	9'5	170	5 4
3	9'5	145	5'5
4	9'5	127	6'2
5	9'5	111	6'5
6	9'5	77	7'7
7	9'5	62	7'8
8	9'5	54	7'7
9	9'5	47	7'4

In this case the induction increases throughout the larger extent of the movement of the brush. But in this machine the knee of the characteristic curve is reached at about 13 ampères, while in the other machine it is found at seven ampères. The armature reaction in this older machine when run at ten ampères is relatively less than in the other one run with the same current. This is further evident from the fact that with the old Gramme run at ten ampères an increase in the current, due to lessening the external resistance, is always accompanied by an increase in the potential difference between the main and the third brush; while

with the ten-light Sperry machine, and others with similarly saturated field, an increase in the current when the brushes are fixed decreases the potential difference between the main and extra third brush. The reason is this: if the field is saturated, but not the armature, an increase in the current does not appreciably increase the field, but it does increase the armature reaction, and so cuts down the total potential difference between the main brushes as well as between one main and a third brush; while with an unsaturated field and a magnetically weaker armature, an incre-

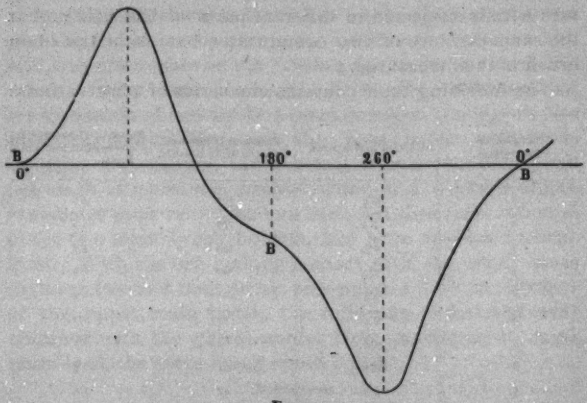

FIG. 2.

ment of the main current produces a greater increment in the field than in the armature reaction. With the same old Gramme machine run at about eighteen ampères, an increment in the current produces a decrease in the potential difference both between the main brushes and the main and third brush. The armature reaction then becomes relatively larger than the increase in the field magnetism. But this old machine exhibits perfectly the property of governing by rocking forward the brushes on a diminishing load, with no more sparking in one position of the brushes than in another.

Hence it is clear that for practically sparkless commutation it is not necessary that the induction *near* but *under* the brush shall be a constant. The effective means by which, with constant current, the brushes can be set in any plane round the commutator cylinder is the reactive effect of the armature. This fact is brought out quite clearly by plotting the integrated potential differences between the upper or positive brush and the third movable one as ordinates to a horizontal line. The data are the same as were employed to plot the first curve in *Fig. 1*. If *Fig. 2* is examined a decided flattening in the curve will be found at 180°, the position of the negative brush. The same flattening may be seen at 0°. All curves plotted with data obtained at different loads show the same diminution or stay of the inductive process near the poles of the armature. The armature at these points paralyzes the field. As the poles of the armature move around they sweep away the lines of force of the field, and only enough remain to produce an electro-motive force competent to offset the electro-motive force of self-induction and in addition cause the newly directed current to grow to its normal value as the coil passes out from under the brush.

This reactive power of the armature may be utilized to effect approximate regulation for constant current without brush-shifting. But for this purpose the load cannot be a maximum. The poles of the armature must be far enough forward to produce increase of magnetic leakage. As an example of what I mean, a forty-light machine had its brushes locked in such a position that it maintained thirty lights with ten ampères current. Ten lights were then cut off, and then ten more, with but small increase of sparking, and the ammeter showed an increase of current from ten to twelve ampères only. A change of two ampères is within limits possible for practical lighting. The machine was then completely short-circuited by placing a large bar of iron across its terminals without dangerous sparking. This means that the characteristic of the machine beyond the crown of the curve approached a vertical line, the ideal characteristic of an automatic constant current dynamo.

The conditions requisite for sparkless commutation of a constant current machine are therefore quite clearly defined. The self-induction of the short-circuited coils must nearly balance the field in all positions of the brushes. Both Mr. Esson, in a paper before the British Institute of Electrical Engineers,* and Professor Ryan, in a paper before the American Institute of Electrical Engineers,† lay down the conditions that the brushes must be kept under the pole faces in order not to enter the weakened field between the pole corners. And yet I have seen constant current machines working with the brushes beyond the extreme tips of the poles with no increase of sparking. I do not regard this condition as absolutely essential, since at maximum electro-motive force the brushes may be moved through a considerable angle without appreciable change in sparking.

Professor Ryan states, in his paper above referred to, that "the magnetizing force impressed by the field ampère-turns must be uniform at all points between the pole faces." This condition is favorable to sparkless commutation, but not essential. It has to do with the area of the sparkless position of the brushes for any given load. If the field is fairly uniform this area will be about the same in different parts of the polar faces; if the field is far from uniform sparkless commutation may yet be secured, but a smaller variation in the current will produce sparking than when the field is uniform, for the sparkless area on either side of the brush with a given external resistance is then much reduced. The region controlled by the armature poles is more limited in extent than when the field is uniform.

It follows that the single magnet type of field is not suitable for a constant current machine. This fact was remarked upon by Mr. Esson. For a two-pole machine the double magnet type is to be preferred. If then the iron is reduced at the back opposite the middle of the polar surfaces and the poles are thickened and rounded off rather blunt at the ends to prevent saturation, the field induction will be suffi-

* *London Electrician*, March 21, 1890.

† *Proceedings*, Vol. VIII, p. 465.

ciently uniform without the necessity of resorting to the chopping away process applied to an English single magnet machine, described in Slingo & Brooker's *Electrical Engineering*.

Quoting again from Professor Ryan: "the air-gap is made of such a depth that the ampère-turns required to set up the magnetization through the armature, without current, and for the production of the highest electro-motive force that the machine will be called on to give, shall be a little more than the armature ampère-turns when it furnishes its normal current. Then as long as the brushes are kept under the pole faces, the non-sparking point will be wherever the brushes are placed. This will be the case whether the armature is or is not saturated." Again, "the impressed field ampère-turns are in excess of the armature ampère-turns by that amount which is just sufficient to produce a weak positive field that will reverse the current in the coil when its terminal bars at the commutator pass under the brush." This latter statement appears to be borne out by the data given, but the machine experimented upon was one giving a maximum of only thirty-five volts and twenty-two ampères, and its performance can scarcely be considered a sufficient guide for the design of machines required to furnish several thousand volts and a current of from 9·5 to ten ampères. Again, I have known a forty-light machine converted into a fifty-light without any change in the field whatever. The armature either contained more iron or was wound with a larger number of turns of wire. Both methods have been followed without effect on the sparking. The first method leaves the armature ampère-turns the same; the second increases them twenty-five per cent. If the relation pointed out by Professor Ryan holds in the first armature it cannot also hold in the second with such a material increase in armature-turns.

Further, if this relation does hold there still remains unanswered the question of relative cross-section of iron in armature and field. Shall the core of the armature be saturated or not? Mr. Esson says that 17,000 lines per square centimeter is the best practice in England for constant potential machines.

I know of one constant current machine in which the armature core is forced well up toward the highest saturation obtainable in a dynamo machine. It is able to produce very high electro-motive force, but it does not govern sparklessly by means of a single pair of brushes. Two other types of machine of which I have data work with about 11,000 lines per square centimeter in the armature. In both of these recent changes are along the line of increasing iron and decreasing copper in the armature. I have explicity advised the use of more iron in the armature for two years. One manufacturer recently told me that he is now following my advice with most gratifying results. With the same number of turns on the armature the output is greatly increased. To what extent the iron in the armature can be increased is an open question. It has now been carried beyond a cross-section equal to seventy-five per cent. of the wrought iron in the field cores. If increased cross-section of the core introduces sparking, this can be avoided by increasing the number of bars on the commutator so as to decrease the self-induction in the section under short-circuit by the brush. Indeed, if the output is kept the same, increase of iron decreases turns of wire, and to that extent decreases self-induction. In a machine with two pairs of brushes the effect is to diminish the angular embrace of each pair.

It is interesting to compare two machines of almost exactly the same capacity, but differing widely in relative core section and armature-turns. Let the two machines be represented by A and B. The data of the two are given in the following table:

Machine.	Total Volts.	Revolutions per Minute.	Segments in Commutator.	Turns per Segment.	Total Turns.	Cross-section of Iron. Square Inch	Lines per Square Inch.
A.	2,900	1,000	130	36	4,752	265	70,800
B.	2,800	875	120	72	8,640	14	79,000

The maximum number of lines of force running through the armature of the A machine is 3,650,000; of the B

machine, 2,213,000. The two machines are designed for the same current of a little under ten ampères. The ratio of the ampère-turns on the armatures of the two is nearly inversely as the cross-section of their iron cores. The ampère-turns on the B armature is eighty-two per cent. greater than on the A armature. It is not probable that the field ampère-turns on B is eighty-two per cent. in excess of those on A. Unfortunately, those particular data are lacking, but the magnetic circuit of A is quite as good as that of B. It does not appear at all probable, therefore, that Professor Ryan's rule applies to both machines.

It is gratifying to our national pride that American designers have successfully carried the Gramme ring constant current dynamo to an output far beyond what some foreign electricians with more theory and less practice in this direction still declare to be impracticable. The writer of a series of articles, now running in the London *Electrical Review*,* says: "beyond about 1,000 volts it is found, in general, to be impracticable to work a closed-coil armature; for either there will be a wasteful lead, or there will be vicious sparking under the brushes, or the current will flash from strip to strip, and will destroy the commutator." * * * "It seems more than probable that machines of that kind will not stand any serious alteration of load if worked at higher voltages, owing to the great range of lead which would be required, and the consequent sparking and flashing over." Again he says: "there is of necessity a large armature reaction in certain forms of arc light machines; and when this is the case, the brushes would require to be shifted right into the centre of the pole arc before sparking would cease, if there were very many turns on each section. The wastefulness of this practice consists in the large number of back-turns and cross-turns which it involves." But in the face of such declarations as these a large number of American machines are now running at an output of 9·6 ampères and from 5,000 to 10,000 volts. A very considerable number of closed-coil

* *Electrical Review*, August 25, 1893.

Gramme rings giving 5,000 volts are in actual use without breakdown, and without any of the fatal drawbacks predicted by the writer quoted.

The design of closed coil Gramme rings for high potential arc lighting has thus far been limited to the two-pole type of field magnet. This involves the maintenance of higher speed than engineers find desirable. The conditions of present practice and the requirements for the immediate future demand a new departure in this class of dynamo design. All indications point toward a multipolar machine of about fifty kilo-watts capacity and slow speed. The armature will contain a liberal amount of iron, much larger than would be found desirable for constant potential machines. Such a dynamo is already in demand, and it will find an immediate field for the lighting of large cities.

THE RESISTANCE OF SHIPS.

BY RICHARD LANO NEWMAN.

[*A paper read before the Section of Engineers and Naval Architects, January 24, 1894.*]

No branch of the theory of naval architecture has a richer literature than that which forms the subject of this paper. It would be a formidable task merely to enumerate the names of eminent mathematicians, and experimentalists who have endeavored to discover the laws of the resistance which water offers to the progress of ships, and still more formidable would be any attempt to describe the very various theories that have been devised. Again and again, has the discovery been announced of the "form of least resistance," but none of these have largely influenced the practical work of designing ships, nor can any be regarded as resting on a thoroughly scientific basis. In fact, at the present time it is generally accepted as a fact, that the problem is one that pure theory can never be expected to solve.

Before dealing with what is generally known as the modern theory (*i. e.*, the stream line theory, on which the most successful of our high-speed ships have been built), let us take a brief glance at what a few of the many workers in this field of science have contributed to the solution of the problem during the past 150 years.

Foremost among those who have investigated this difficult problem is Sir Isaac Newton, who, in the second book of his *Principia*, has demonstrated that the resistance opposed to bodies which move in a fluid varies as the square of the velocity of the body; but this has been proved to be applicable only to bodies having comparatively low velocities. It is evident, therefore, that a theory based on such conditions would not be applicable to naval architecture, one of the objects of which is to obtain high velocities.

Following Newton came Daniel Bernoulli. He considered that the resistance should be represented by two terms, one denoting the square of the velocity, the other being a constant; but this was opposed by D'Alembert, who carried on his enquiries in a different manner, and succeeded in representing the theory of fluids in a more general formula than had hitherto been done.

In attempting to apply a theory of resistance to naval architecture, most of the authors of the greatest eminence who wrote on this subject down to the time of the Abbé Bossut followed Newton in supposing the resistance to vary as the square of the velocity; for, up to this time, the theory that affirmed this to be correct had not been shown to be erroneous.

In the year 1775, a series of experiments was made at Paris, under the direction of the Comptroller-General of Finances, with the assistance of the Abbé Bossut, M. D'Alembert and the Marquis de Condorcet. The magnitude of these experiments exceeded anything that had hitherto been attempted in this direction. The experiments were first carried out with the object of testing the then existing theories, and if none of them could be verified, to procure data to serve as a basis for a new solution.

The Abbé Bossut remarked, in his report, that that advice

was the more conclusive, as M. D'Alembert had solved the question by a new and strictly analytical method, which would leave nothing to be wished for, could the equations which are deduced be integrated, either by converging series, or by any other method. But unfortunately this was the point on which they failed. The results of these experiments did not agree with any of the then known theories, as they all previously supposed the resistance to vary as the square of the velocity. Although an investigation of the tabulated results would prove very interesting, it must suffice for our purpose to give a brief summary of the report, as time will not permit a further investigation.

Summary of Report.—The resistances experienced by the same body, whatever may be its figure, moved with different velocities through a fluid infinite in extent, are very nearly in proportion to the squares of the velocities. It has been shown that the resistance varies in a rather greater ratio than that of the square. Experiment, therefore, agrees on this point very nearly with theory. (Here we must remember that the velocities at which the models were propelled were comparatively low, the highest being only 260 feet per minute.)

The resistance which arises from motion in oblique directions do not diminish, everything else remaining the same, in proportion to the square of the sines of the angles of incidence; therefore, on this head, the common theory of the resistance of fluid should be abandoned altogether, when the angles of incidence are small; as then the results deduced from it would be erroneous. It is evident, also, that it cannot be employed to find the solid of least resistance, nor generally to determine any curve, for in such problems the law of the curvature is an unknown element; but for curves in which the angles of incidence are large, as from 50° to 90°, we may make use of the theory; always remembering that the resistance which will result will be rather less than those given by experiment, and that the error will be greater in proportion as the angles of incidence are smaller.

It is also interesting to note that these same investi-

gators touched on the question of resistance as affected by the depth of water, and their experiments proved conclusively that this item was not to be neglected. Of the truth of this law, we have quite recently had an illustration viz: when the cruiser *New York* went on her official run.

The Chevalier du Buat deduced from his experiments a conclusion directly at variance with the common theory, and I only give it, that you may compare it with that now generally accepted. He gave the result of his experiments which present the following ratio: The pressure of a stream on the anterior surface of a stationary body being 1, that on a body moving through a still fluid is only 0·843. Whatever may have been the cause of the difference he observed, the result showed that the subject requires further investigation by practical means.

A paper on this subject, in the *Encyclopædia Britannica*, contains the suggestion of the existence of a quantity of stagnant fluid at the anterior and posterior parts of the body; but Du Buat arrived at the conclusion that the water at the head of a vessel is not perfectly stagnant; but that it recedes in filaments, from the axis, in curves which converge to the surface of the vessel, and ultimately escapes with an accelerated velocities round its sides.

The same author continues that if it were fully established that there is a quantity of water stagnant, or nearly stagnant, the next step to be considered would be that form of the extremities which would reduce this quantity of stagnant water to a minimum.

Now, at first sight this seems a peculiar theory, but, if carefully looked into, it will be found to compare favorably with our present views, especially in respect of the latter portion.

The same investigator also proved that by adding to a cubical body so as to make its length three times its breadth, its resistance was considerably reduced, showing, as you see, that in these early days it was recognized that the length of a ship was a factor to be considered in relation to the question of her speed.

Another worker in this field was Don George Juan, a

Spanish nobleman of high rank in the naval service of his country, and a member of most of the principle scientific bodies in Europe. To attempt an explanation of his theory would be rather beyond the scope of this paper, and would, I am afraid, prove of little service to us, as he bases his theory on the assumption that the resistance will vary as the hydrostatic head; but those who desire to examine his views will find them set forth in the first volume of Creuze's *Naval Architecture*.

Between the years 1796 and 1798, some very exhaustive experiments were made by the Society for the Improvement of Naval Architecture, at the Greenland Dock, London, England. They showed that the power of the velocity of the bodies used in the experiments of the year 1798, at two miles per hour, was, in general, a little above the square, but that the ratio gradually decreases as the velocity increases, and becomes a little less than the square at the velocity of eight miles per hour. And, with respect to the bodies used in the year 1796, it also appears that the power of the velocity, with the said bodies, is considerably less than that of the bodies used in 1798, and is always less than the square. This difference in the power of the velocity of 1798 and 1796, arises from the bodies used in 1796 having a much greater surface exposed to frictional resistance than the bodies used in 1798, and also because the said friction always increases in a much smaller ratio than the square. So that the friction of the bodies used in 1796 forms a greater proportional part of their total resistance than it does in the bodies used in 1798.

Colonel Beaufoy, who was engaged on the foregoing experiments, at a later date continued his investigations to test the correctness of the formulæ:

Oblique resistance = direct resistance $\times$ $\sin^{3}\theta$, and he succeeded in proving the assumption to be incorrect, but we will revert to this subject later on.

In the year 1806, Admiral F. H. Chapman, of the Swedish Royal Navy (who had previously developed a theory of resistance which in itself is rather a curiosity), gave to the world the labors of the later years of his life, in which he

advocates the parabolic system of constructing ships. What he did was to base his reasonings on the results of ships which had been found to possess good qualities, and then subjecting the same to scientific investigation. He began by endeavoring to discover whether the reduction of the areas of the transverse sections in well-constructed ships followed any law. For this purpose he calculated the areas of the sections of several ships; and in order to make the numbers more convenient, he divided the areas by the breadth of the midship section; then setting off from the water-line, at the respective stations on the drawing, distances equal to the quotients, he traced a curve representing the areas, which he called a curve of sections. He then endeavored to find the equation to the curve, or rather, that of another curve which would coincide with this for the greatest length; he found that if the power and parameter of a parabola were so determined as to allow that curve to pass through three given points of the curve of sections, the two curves would nearly coincide. Chapman consequently concluded that if the areas of the several sections of a ship were made to follow the law of the abscissæ of a parabola, a vessel of good qualities might be formed. This, as you see, is opposed to the theory of M. Romme, who inferred, from his experiments, that it made no difference whether the water was divided by a curved surface or by a plane surface, being the chord of such curve.

Now, gentlemen, having taken a rough survey of what some of the most eminent workers in this field have done, we will come down to the early sixties, and see what progress had taken place up to that time.

In the year 1863, a naval architect, in advocating the probability of crossing the Atlantic in one-half the time then occupied, made the following remark, which in itself seems to me to be more or less of an apology for the rashness of his statement: "our present necessities demand a class of vessels that will reduce the voyage between Europe and America to an average of one-half the time, and at a cheaper rate. I have endeavored to indicate how, I think,

this may be accomplished, and trust that my ideas may be regarded by the enterprising merchants of this country, if not by the admiralty, as worthy of consideration. If the thousands of intellects at work on this problem did not believe that it was susceptible of a solution, it would indicate a species of wide-spread monomania. I simply believe that the prevailing sentiment and conviction foreshadows the event."

At the present time we know that the event is not only possible but an accomplished fact, and the several causes that have enabled us to accomplish it may be enumerated as follows:

(1) Improved methods and materials used in construction.

(2) Recent researches to establish the form of least resistance, turning principally on the modern theory of resistance.

(3) Improvements in the machinery used for propulsion, etc.

In the year 1862, a number of experiments were made with H. B. M. SS. *Warrior* and *Black Prince*. As these ships were built from the same drawings, and the engines were built by the same firm from one set of patterns, it might reasonably have been supposed, under these circumstances, that the two ships would have been as nearly as possible equal in speed; but the results proved the *Black Prince* to be the slower boat by at least one knot. The reasons assigned to account for this at the time were many and unreliable. One expert stated the cause as follows: On trial the *Black Prince* drew eight and one-half inches more water than her sister ship, consequently her resistance would be greatly augmented. He says: "in the aggregate, I estimate the law of resistance to be according to arithmetical progression. That is, if the resistance to a solid body, moving at a given velocity, be represented by 1 at the first foot from the surface, it will be 2 at the second, 3 at the third, and so on." This is entirely opposed to our modern theory, and to which I particularly wish to draw your attention, as I have no doubt some of my hearers hold views on this subject similar to those which I at

one time did, and which upon investigation I found to be erroneous.

Mr. Scott Russell, who was a great authority on all subjects connected with ship-building, used to compute the probable resistance of a ship in the following manner. He had ascertained that at ten knots per hour, with a vessel of what he termed the proper form (?) of 1,500 tons burden, the head resistance could be reduced to fifty pounds per square foot. He had also ascertained how much a similar vessel could be propelled with, by engine power alone, including the loss due to the working of the engines, and he found that whilst the direct resistance to a ship going ten knots per hour was only fifty pounds per square foot of midship section, including all loss from communication by paddle wheels, air pumps and other sources, except the slip, this resistance was not more than sixty-five pounds per square foot of midship section. Thus he could calculate confidently to a quarter of a knot, as he had done for many years with his peculiar shape of ship, the amount of power necessary to propel a given ship at a given speed; for instance, where a speed of ten knots was desired he provided fifty pounds per square foot of midship section, for the resistance of that ship; and when he had to overcome the resistance of the machinery also, he made this up to sixty-five pounds per square foot.

This in all probability was a very good rough-and-ready rule for the then comparatively low speeds run, but, as you see, it only involves the midship section, and had he used this rule for higher velocities, he would have found that there were other conditions to be considered.

The Stream Line Theory.—Many eminent English mathematicians have been concerned in the introduction and development of this theory, but chief among them are the late Professor Rankine and the late Mr. W. Froude. The former practically applied the theory to calculations (see his treatise on *Ship-building, Theoretical and Practical*), and the latter for years conducted experiments for the British Admiralty, beyond all comparison in value with any that have gone before them. Since his death, his son has continued the

experiments on the lines laid down by the father, the results of which may be judged by the number of high-speed ships now traversing the ocean.

Water, as you know, is not a perfect fluid; that is to say, its particles do not move past one another with perfect freedom, but exercises a certain amount of rubbing or *friction* upon one another, and upon any body past which they move. Suppose a thin board with a plane surface to be moved through water. It will experience what is known as *frictional resistance*. The amount of this resistance will depend upon the area and the length of the plane, as well as its degree of roughness and the rate of its motion. If this same plane be moved in a direction at right angles to its surface, it experiences what is termed *direct* or *head* resist-

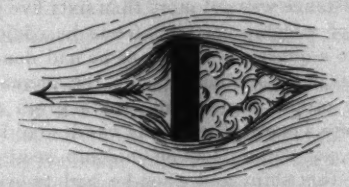

FIG. 1.

ance, the amount of which depends on the area of the plane and the rate of its motion. Should the plane be moved obliquely it experiences a resistance which may be regarded as a resultant of *frictional* and *direct* resistance.

Suppose either of those resistances to take place, the plane would leave an eddying *wake* behind it, as indicated by *Fig. 1*, and this disturbance among the particles of water is a very important element to the resistance of the body. If the plane is not wholly immersed, or its upper edge is near the surface, it will heap up water in the front as it advances, and create waves which will pass off into the surrounding water, to be succeeded by others. Such wave-making requires the expenditure of power, and constitutes a virtual increase in the resistance. If the plane were wholly immersed, it would create little or no surface disturbance,

and, consequently, the body would require less force to propel it at a given speed. If there were no surface disturbance, the resistance would remain constant, irrespective of the depth of immersion. This statement is directly opposed to the opinion, frequently entertained, which confuses the greater hydrostatical pressure on the plane, due to its deeper immersion, with the dynamical conditions incidental to motion. It may, therefore, be desirable to add a brief explanation.

Suppose a plane to be deeply immersed; it is evident that the forces on its back and front balance one another at any depth. Now suppose the plane to be in motion, at each instant it has to impart a certain amount of motion to the water disturbed by its passage, but the momentum thus produced is not influenced by the hydrostatic pressure on the plane corresponding to its immersion. Water being practically incompressible, the weight of water set in motion will be constant at any assigned speed, and consequently the resistance, neglecting of course any surface disturbance. For instance, Colonel Beaufoy proved by experiment that the resistance of a plane moving normally to itself, at depths of three, six and nine feet below the surface, were practically identical. The following rule was also established as the result of these experiments. The resistance per square foot of area, sustained by a wholly submerged plane moving normally to itself through sea-water at a uniform speed of ten feet per second (which is very near six knots per hour), is 112 pounds; and for other speeds, the resistances vary as the square of the speed.

As before stated, Colonel Beaufoy also showed that the oblique resistance was not equal to the direct resistance $\times$ sin^2 of the angle of incidence. Table II contains a summary of his results.

Angle of Plane with Line of Motion.	90°	80°	70°	60°	50°	40°	30°	20°	10°
Sines of angles, . .	1'	·985	·940	·866	·766	·643	·5	·342	·174
(Sines)^2 of angles, .	1'	·97	·88	·75	·587	·413	·25	·177	·03
Resistances, ...	1·00	·915	·845	·808	·722	·579	—	·321	·272

From this table it appears that up to angles of 50° to 60°, the resistance varies with a fair approach to agreement, but for angles from 50° down there is a considerable difference.

The theoretically correct law has been determined by Lord Rayleigh, and is as follows:

Let P = the direct resistance, and P' the corresponding resistance due to the inclination of the surface.

Then

$$P' = \frac{2\pi \sin a}{4 + \pi \sin a} \times P = \frac{Sin\ a}{\cdot 637 + \cdot 5\ sin\ a} \times P$$

In Table II the results of this formula is shown:

Angle of Plane with Line of Motion.	90°	80°	70°	60°	50°	40°	30°	20°	10°
Sines of angles, . .	1·	·985	·940	·866	·766	·643	·5	·342	·174
P', ...	—	·872	·849	·809	·7509	·6708	·56	·423	·2403
Resistances, ...	1·00	·915	·845	·828	·722	·579	—	·321	·272

This formula takes no account of the negative pressure on the back surface of the plane.

M. Joëssel, of the French Navy, has conducted a series of valuable experiments on the same subject, and has deduced therefrom a formula similar in form but not identical with Lord Rayleigh's. It is as follows:

$$P' = \frac{sin\ a}{\cdot 39 + \cdot 61\ sin\ a} \times P$$

In Table III the result of this formula is shown:

Angle of Plane with Line of Motion.	90°	80°	70°	60°	50°	40°	30°	20°	10°
Sines of angles, .	1·	·955	·940	·866	·766	·643	·5	·342	·174
P', ...	—	—	—	—	—	—	—	—	—
Resistances, ...	1·	·915	·845	·828	·722	·579	—	·321	·272

Frictional resistance is measured by the momentum imparted to the water in a unit of time; this momentum being imparted, at each instance, to a current or *skin* of

water, which is adjacent to the surface. The extent to which the frictional resistance causes disturbance—that is to say, the "thickness of the skin"—varies with the velocity and other circumstances of the motion. From instant to instant the frictional current thus created is left behind in the form of a "frictional wake," which follows the surface. The governing conditions of the frictional resistance are the area and length of the plane, its degree of roughness and the speed of advance.

The following are a few of the experiments of the late Mr. Froude, as summarized by himself.

Nature of Surface.	Length of Surface or Distances from Cut-water, in Feet.											
	2 feet.			8 feet.			20 feet.			50 feet.		
	A	B	C	A	B	C	A	B	C	A	B	C
Varnish, ...	2·09	·41	·390	1·85	·325	·264	1·85	·278	·240	1·83	·250	·226
Paraffine, ...	1·95	·38	·370	1·94	·314	·260	1·93	·271	·237	—	—	—
Tinfoil, ...	2·16	·30	·295	1·99	·278	·263	1·90	·262	·244	1·83	·246	·232
Calico, ...	1·93	·87	·725	1·92	·626	·504	1·89	·531	·447	1·87	·474	·423
Fine sand, ...	2·00	·81	·690	2·00	·583	·450	2·00	·480	·384	2·06	·405	·337
Medium sand, . .	2·00	·90	·730	2·00	·625	·488	2·00	·534	·465	2·00	·488	·456
Coarse sand, . . .	2·00	1·10	·880	2·00	·714	·520	2·00	·588	·490	—	—	—

He says: "This table represents the resistances per square foot due to various lengths of surface, of various qualities, when moving with a standard speed of 600 feet per minute, accompanied by figures denoting the power of the speed to which the resistances, if calculated for other speeds, must be taken as approximately proportional.

"Under the figure denoting the length of surface in each case are three columns, *A*, *B*, *C*, which are referenced as follows:

"*A*. Power of speed to which resistance is approximately proportional.

"*B*. Resistance in pounds per square foot of surface, the length of which is that specified in the heading, taken as the mean resistance for the whole lengths.

"*C.* Resistance per square foot on unit of surface, at the distance sternward from the cut-water specified in the heading."

From these experiments the following deductions have been made:

(1) That the law formerly assumed to hold is very nearly conformed to, the frictional resistance varying approximately as the square of the velocity, when the area, length and condition of the surface remains unchanged.

(2) That the length of the surface sensibly affects the mean resistance per square foot of wetted surface; especially so when very short lengths are compared with planes of fifty feet and upward. For greater lengths than fifty feet it appears that the mean resistance per square foot of area remains nearly constant. Mr. Froude explains this important experimental fact as follows: The portion of surface that goes first in the line of motion, in experiencing resistance from the water, must in turn communicate motion to the water in the direction in which it is itself travelling; consequently, that portion of the surface which succeeds the first will be rubbing, not against stationary water, but against water partially moving in its own direction, and cannot, therefore, experience as much resistance from it.

A third important deduction is the great increase in frictional resistance due to a very slight difference in the apparent roughness of the surface. For instance, the frictional resistance of a surface of unbleached calico was shown to be about double that of a varnish surface, and a varnished surface gave results about equal to that of a surface coated with smooth paint, tallow, or composition such as is generally used on the bottoms of ships. The frictional resistance of such a surface, moving at a speed of 600 feet per minute, would be about one-fourth pound per square foot, which would give a frictional resistance of about one pound per square foot of immersed surface for the clean bottoms of iron ships when moving at a speed of about 12·8 knots. This unit is worth noting.

The foregoing will assist us in following the reasoning

of the more difficult problems connected with the resistance of ship-shaped solid bodies, as it is now generally acknowledged that satisfactory experiments on the resistance of ships can only be made with ship-shaped models of reasonable dimensions.

In the modern theory, the total resistance is considered to be made up of three principal parts:

(1) Frictional resistance due to the gliding of particles over the rough bottom of the ship.

(2) "Eddy-making" resistance at the stern.

(3) Surface disturbance, or wave-making resistance.

The second of these divisions only acquire importance in exceptional cases; it is known to be very small in well-formed ships. We will, therefore, bestow most attention upon frictional and wave-making resistance, examine the conditions governing each, and contrast their relative importance. In considering this subject we will assume the ship is either dragged or driven at a uniform speed by some external force which does not affect the flow of water relatively to her sides. The reason for this is to enable us to consider those resistances which are affected by the ship's form, the condition of her bottom, etc., whereas there are other conditions to be considered when treating of propulsion and which I hope to touch on before finishing this paper, as the compilation of these notes was first intended for my own information only, and to enable me, if possible, to obtain a clearer insight into those several elements that constitute the total resistance of a ship.

Suppose the ship to be moving ahead at a given velocity through an ocean unlimited in extent, and motionless relatively to the ship other than the disturbance caused by her passage. Now this would be equivalent, and the condition would remain unchanged if we assume the ship to remain stationary and the ocean to move past it in a direction opposite, and at a velocity equal, to that of the ship. This latter supposition enables us to trace more simply the character of the disturbance caused by the introduction of a hull of a ship at a certain speed into water that was previously undisturbed. Let us also assume the water to be

absolutely frictionless, and the bottom of the ship perfectly smooth. This is of course a hypothetical condition, and is only introduced to enable us at a later stage of the enquiry to arrive at what are the actual conditions.

In *Fig. 2*, let the black body in the centre represent the water-line plan of a ship, and the lines the paths traversed by the water in passing it. If we imagine for a moment the ship to be lifted out of the water, the path traversed by any set of particles would be represented by a straight line running parallel to the centre line of the ship. Now, if we immerse the ship, as indicated by *Fig. 2*, any set of particles in a given stream line will still continue to approach the ship in a direction parallel to her keel until such times as it reaches that sphere influenced by her presence, when their path will be diverted laterally, as indicated by the stream lines. How far in front of a ship her influence would be

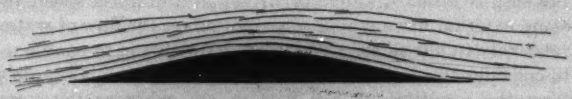

FIG. 2.

felt would, I think, be difficult to conjecture; but there would no doubt be a limit, both in front and at her sides, at which points the water would still continue to move in its original direction. If the foregoing is correct, it follows that with this lateral diversion, and limit to the sphere of influence at the sides, the velocity of flow at the midship section must be accelerated. This acceleration should be gradual, but will depend on three causes:

(1) The velocity of flow.

(2) The bow of the ship.

(3) The breadth of the ship, or the amount of this lateral deflection.

At the broadest part of the ship the velocity of the particles will be the greatest, owing to the fact of the stream line being at its narrowest, and the same quantity of water having to pass as at the foremost area. After the midship

section has been passed the particles should converge gradually toward the keel line, and their speed will again receive a check. Finally, after flowing past the ship, and attaining such a distance astern as to place them beyond the influence of the ship they again attain their original direction and flow, providing there is no surface disturbance. This last-named condition would only be possible in a ship wholly submerged at a great depth below the surface of an ocean limitless in extent. But in actual ships partly immersed, the retardation and acceleration referred to must cause the formation of a bow and stern wave.

[*To be concluded.*]

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Commonwealth of Pennsylvania. Report of Commission Appointed to Investigate the Waste of Coal Mining, with the View to the Utilizing of the Waste. Philadelphia: Allen, Lane & Scott. 1893. 8vo.

Knudsen, A. Triangular Surveys from Single Stations. San Francisco: Brunt & Co. 1893. 18mo.

Van Nostrand Science Series. No. 101. The Sextant and other Reflecting Mathematical Instruments. New York: D. Van Nostrand Company. 1891. 18mo. Price, 50 cents.

Do. No. 105. Determinants, an Introduction to the Study of, with Examples and Applications. New York: D. Van Nostrand Company. 1892. 18mo. Price, 50 cents.

Do. No. 109. The Measurement of Electric Currents. Electrical Measuring Instruments. Meters for Electrical Energy. New York: D. Van Nostrand Company. 1893. 18mo. Price, 50 cents.

Vick's Floral Guide for 1894. Rochester: James Vick's Sons. n. d. 8vo. pph. Price, 10 cents.

American Humane Education Society. Autobiographical Sketches and Personal Recollections of George T. Angell. Boston: Society. n. d. 8vo. pph. Price, 10 cents.

The Strike at Shane's. Gold Mine Series No. 2. Sequel to "Black Beauty." Boston: Society. n. d. 12mo. pph. Price, 10 cents.

BOOK NOTICES.

A Text-book on Electro-magnetism and the Construction of Dynamos. Vol. I. Electro-magnetism and the construction of continuous current dynamos. By Dugald C. Jackson, B.S., C.E. New York and London: Macmillan & Co. 1893. 8vo 281 pp. 132 illustrations. Cloth.

Among the many books on dynamos that have appeared within the last few years, this recent addition, the first volume of which has just appeared, must undoubtedly be classed as one of the best. It is written in a logical, clear and yet concise form, and treats of the fundamental principles and their application in a sufficiently complete manner, without resorting to voluminous padding, old cuts and unnecessary and historical details. The theory of the dynamo is treated from a strictly modern standpoint, and is based upon the latest researches and the best American practice. The treatment is necessarily mathematical, but only so far as is absolutely necessary, all elaborations being omitted, and the reader finds theory and practice combined in a very satisfactory way. The introduction of the calculus and the omission of elementary physics and mechanics and the addition of copious references are all welcome features, as the book is designed as a text-book for college students and others who have had an equal preparation.

The work is divided into two volumes: the first treating of electro-magnetism in general and direct-current dynamos in particular, and the second (to appear soon) of series arc lighting and alternating current machinery.

The first chapter takes up the primary definitions and evaluations and explains very clearly the qualitative and quantitative relations existing in the magnetic circuit. Chapter II includes a brief description of typical electro-magnets and their design for specific work. Chapter III is a discussion of the magnetic properties of iron and includes various methods of experimentally determining permeability and hysteresis, the effect of the physical properties and chemical composition of the iron and the loss of energy in hysteresis, all of which is illustrated by means of useful curves. Chapters IV and V treat respectively of the establishment of electrical pressures and of the magnetic circuit of the dynamo, and include the theory and design of armatures and field magnets. The fundamental principles are developed clearly, the various losses and allowances made in modern practice are given and also several examples of calculations. Chapter VI is devoted to the compensation for cross-turns and the effect of brush contact—an important subject which has hitherto received but little attention in books. Chapter VII is on characteristic curves, the regulation of dynamos and their connection for combined output. The four characteristic curves are described and their determination and interpretation explained. The principles underlying the various methods of regulation and the application of the same, and also the methods of connecting dynamos for parallel working,

are all given in a very satisfactory manner. A chapter, ably discussing the subject of efficiencies and one on multipolar generators concludes the book.

The cuts are new and well made, the typography excellent and the general get-up of the volume displays unusual good taste.

The book is not intended for, nor will it be of much use to, so-called "beginners" and "practical men" and others having little knowledge of physics and mathematics, but to advanced students and those desiring to study the subject of the theory and design of dynamos, it cannot be too highly recommended. H. S. Hg.

Alternating Currents. An analytical and graphical treatment for students and engineers. By Frederick Bedell, Ph.D., and Albert Cushing Crehore, Ph.D. Second edition. New York: The W. J. Johnston Company, Limited, 41 Park Row. London: Whittaker & Co., Paternoster Square. 1893. 8vo. 325 pp. 112 illustrations. Price, $3.

The first edition, which appeared about a year ago, was exhausted in a few months, and the second edition has already appeared. The popularity of the book has been further evidenced by the fact of its translation into the French and German.

For the benefit of those who are not acquainted with this book, it might be well to add that it contains an analytical and graphical treatment of the subject of alternating currents in simple and divided circuits containing resistance, self-induction and capacity, with a view to enabling problems to be solved which involve these quantities.

The discussions are very clear and exact, and can readily be followed by advanced students. The work is divided into two parts: the first containing the analytical, and the second the graphical, treatment. After an introductory chapter on primary definitions and one on harmonic functions, the various combinations of resistance and self-induction, resistance and capacity, and self-induction and capacity are taken up, including oscillating and non-oscillating charges and discharges, etc.

Numerous problems are worked out, and altogether the subject is handled in a logical manner and is well arranged for study, and though of little practical importance, it is nevertheless very useful to students. H. S. Hg.

Transformers. By Caryl D. Haskins. Lynn, Mass.: Bubier Publishing Company, 5 x 7. Cloth. 150 pages. Illustrated.

This book is written specially for use of the central station engineer and the student, and claims to be a semi-technical, yet semi-popular treatise.

The attempt is made to present the subject in a clear and simple style, with scarcely any mathematics, but much of the matter is vague and contains too much of a mixture of simple phrases and complex terms, and the reader misses a logical presentation of the fundamental principles.

Following the introductory matter on induction, comes a demonstration of why alternate currents afford the only "economic means for the distribution of light," and a brief explanation of some of the methods of distribution. Such ambiguous and even incorrect terms as the "creation" of a cur-

rent; "an electric current comes into existence;" "'electrical induction' is that force which 'persuades,' 'actuates' or 'impels' an electrical current in one body by the influence of current in another;" "units of force pushing against" units of force, in speaking of the action of counter electro-motive force; electro-motive force is "the number of volts pressure present at any given point in a circuit," etc., are apt to confuse the reader and give him a very wrong conception of the subject.

In the second chapter, on "theoretic considerations," the questions of self and mutual induction, regulation, electro-magnetism, "magnetic currents," eddy currents, hysteresis, etc., are briefly considered, but it would be difficult for one who is unfamiliar with the subject to understand much about it, from the author's exposition, as many important steps are omitted and fundamental principles only vaguely explained.

It would have been better had the third chapter on "The Theory of the Transformer Mathematically Considered" been omitted, as it is useless to the class of readers for whom the book is designed. It gives a list of symbols to be used in the discussion, and then uses others in the formulæ without explaining what they are. Also, the author says, "a knowledge of algebra only is presumed," yet the equations contain differentials, and little or no explanation is given either of the meaning or the deduction of the expressions, so that only to one familiar with the subject are they intelligible. Symbols are used that are not defined, which makes it still more difficult to follow the argument. There is little in the chapter, except the two pages from S. P. Thompson's *Dynamo-Electric Machinery* which, although intended for advanced students, has been used bodily, with but little change in the text and no adaptation of the treatment to meet the requirements of an elementary book.

The concluding chapters, on the "Evolution of the Transformer," "Transformer Construction," "The Transformer in Service" and "Commercial Transformers" are much better than the preceding ones, and the author is evidently more at home in the description of commercial apparatus and in dealing with practical considerations. These chapters may be read with profit, and go far to atone for the shortcomings of the others.

Several appendices and a short (but unsatisfactory and misleading) glossary of terms, close the book. H. S. H.

King's Hand-Book of New York City. An Outline History and Description of the American Metropolis. With over 1,000 illustrations from photographs made expressly for this work. Edited and published by Moses King, Boston, Mass. 1893. Second edition. Price, $2.

This work is one of the best of its kind that we have ever seen—so much in advance of the average guide-book that comparison is out of the question. It is introduced by an extremely interesting historical sketch of the city from its foundation, through the various prominent periods of its growth, to the present; and then proceeds to take up in order the various features and institutions of the city, giving in condensed form a surprising amount of information on every topic of local interest, including practically everything the

visitor would be likely to seek to know, and much that the native will find of value to have in convenient form for ready reference. It is, in brief, a carefully prepared digest of information concerning the history, municipal government, commerce, trade, manufactures, financial, educational, benevolent institutions, public and other prominent buildings, parks, places of local or historical interest, etc., presented in a form unusually complete for a work of its class. The profusion and general excellence of the illustrations, all of which are new, add greatly to the utility and attractiveness of the work.

W.

The Measurements of Electrical Currents and other Advance Primers of Electricity. By Edwin J. Houston, A.M. New York: The W. J. Johnston Company, Limited, 41 Park Row. 429 pages. 169 illustrations. Price, $1.

Electrical measurements and other advanced primers of electricity forms the second volume of Professor Houston's series of elementary electrical treatises, for students and non-technical readers. A third volume will complete the series, but there is no necessary connection between the several volumes, each being complete in itself, as likewise are the several primers in each volume, so far as the subjects will permit.

The book derives its title from the first three primers, which relate to the measurements of electric currents, electro-motive forces and resistances, respectively. The object of these primers is not so much to teach the practical operations of electrical measurements as to explain in simple, but exact terms, the principles upon which they are based and to describe the apparatus used.

Two primers treat of voltaic and thermo-electrical cells and other sources of electricity. The principles of commercial measurements are explained in three primers, and nine others are devoted to dynamos, motors and transformers; the eighteenth and last primer being a review of primer or primers.

The 200 and odd pages on electric lighting and power deal very thoroughly with the different methods and apparatus in practical use. This section will be particularly useful to the large class who wish to obtain a correct knowledge of the applications of electricity. The author's lucid and accurate exposition of general principles will be appreciated by advanced students and practical electrical operatives.

W.

Universal Bimetallism and an International Monetary Clearing House, together with a Record of the World's Money, Statistics of Gold and Silver, etc. By Richard P. Rothwell. New York: The Scientific Publishing Company. 1893. Pp. 53. Price, 75 cents.

The author of this treatise, the editor of the leading mining journal of the United States believes that the time has come when the silver problem should be permanently solved by international agreement providing for universal bimetallism. The specific plan which he proposes for acceptance is ably elucidated and advocated in the pamphlet, and has received high praise from many experts, who have given the subject the most careful consideration.

W.

How to Make Inventions, or Inventing as a Science and an Art. A practical guide for inventors. By Edward P. Thompson, M.E. (Illustrated by Wm. A. Courtland.) Second edition, revised and enlarged. New York: D. Van Nostrand Company. n. d.

The scope of this work is original and purports to be highly practical. Whether it shall prove possible, as the author anticipates, to induce in would-be inventors correct habits of thought and reasoning in the development of their ideas may well be doubted. That, in the case of those already prepared by previous education and training in the rudiments of the scientific method, it will prove an interesting and suggestive book we have no doubt. In such cases, the seed will fall on good ground, and will bear good fruit. The vast majority of so-called inventors, whose fees go to swell the coffers of the Patent Office, and whose creations are brought to light only to be buried beyond hope of resurrection in the massive tomes which issue monthly from its portals, will go on grinding out useless inventions in the old hap-hazard way.

The author's ideas, as advanced in the book, are admirable and worthy of praise, but the trouble about utilizing them lies here. Those who are capable of appreciating and applying his analytical methods, belong to the class that have no need for the book; while of those whom it could benefit, the great majority are persons of untrained and unbalanced minds, who either could not think logically if they would, or would not if they could.

This, however, does not detract from the merit of Mr. Thompson's book, the plan of which is excellently conceived and well carried out. W.

The Ore Deposits of the United States. By J. F. Kemp, A.B., E.M. 4to, pp. 302. Cloth. Numerous illustrations. New York: The Scientific Publishing Company, 27 Park Place. 1893. Price, $4.

The material for this volume was originally collected for service in connection with lectures and instruction given by the author during the past seven years, first at Cornell University and later at Columbia College.

Outside of the transactions of our technical societies, there was, until the appearance of Professor Kemp's book, no source of information accessible to the student and investigator of this important subject. Whitney's *Metallic Wealth of the United States*, published in 1854, an excellent review of our ore deposits in its day, has long since become antiquated, and the few general treatises on the subject are those of foreign authors, in which, while general principles are admirably presented and discussed, there is no information of a descriptive nature relating to American occurrences that are of value to American students. The truth of this statement will become more apparent when it is considered that many of the most important sources of ores in the United States have only been developed within the past decade. Aside from all this, however, it will be admitted that a work of this comprehensive character can only properly be undertaken by one who, like the author, has had the opportunity of making personal observation and study of the formations and locations, and who is thoroughly conversant with the literature of

the subject and able to give to the views and opinions of authorities, often conflicting, their due and proper weight.

There is no one in the United States better qualified than Professor Kemp in respect of professional attainments and practical acquaintance with the subject, to treat it satisfactorily, and he has made a book which will be welcomed by all who are interested in the ore deposits of the United States, as a trustworthy guide. W.

A Manual of Practical Assaying. By H. Van F. Furman, E.M. Third edition. New York: John Wiley & Sons. 1893. Price, $3.

This volume appears to be exceedingly well planned, and should be found a satisfactory guide book for the practical assayer and chemist engaged in commercial analytical work. The chapters on rapid methods of gas and water analysis should prove of much service, as commercial work of this nature is becoming important. The writing of chemical equations and stoichiometry are subjects which are not usually treated of in works of this class with the elaboration which the author gives them, and should add to the usefulness of the work.

Somewhat more attention, in our judgment, might have been usefully devoted to the electrolytic methods, which the labors of Classen, Smith and others have made familiar to students.

The tables at the close of the volume are numerous and particularly useful.

As a whole the work is a very satisfactory one, and will doubtless find a large demand. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 21, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, seventy-four members and eight visitors.

Additions to membership since last report, seventy-six.

Prof. Wm. Libbey, Jr., of Princeton, N. J., who was present by invitation, gave an interesting account of the physical geography of the Hawaiian Islands, illustrating his remarks with lantern views. The meeting passed a vote of thanks to the speaker for his extremely instructive and entertaining address.

Mr. Joseph Richards exhibited and described a specific gravity balance which he had devised for the purpose of automatically registering the percentage of tin in solders. The beam of this balance is accurately graduated

by experimental observation of the record made by a series of carefully prepared alloys of tin and lead. An equal volume of the samples of each composition obtained by casting in a mould, being used for the purpose of standardizing the scale beam. The mode of using the balance consists simply in melting a sample of the solder to be valued, casting the test piece in the mould provided for the purpose, introducing this in a cup made to receive it on the short arm of the lever, and shifting a movable weight along the long arm of the balance until equilibrium is established. The percentage of tin in the sample is then read off directly on the beam. The apparatus is found very convenient by purchasers of solders and especially by purchasers of old solders recovered from waste.

The Secretary gave some account of the work of the Niagara Falls Power Company.

Mr. Samuel Sartain offered the following substitute for paragraph 1 of the special rules for the award of the Elliott Cresson Medal passed by the Institute at its stated meeting of September 20, 1893, to-wit:

(1) "Upon the adoption, by the Committee on Science and the Arts, of a report setting forth that a discovery, invention, improvement or manufacture is worthy of an award of the Elliott Cresson Medal, publication shall be made three times in the *Journal of the Franklin Institute*, stating that at the expiration of three months from the date of the first publication, the applicant will be entitled to receive the award of the said medal, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality or merit, of the supposed discovery, invention, improvement or manufacture."

The mover explained that the changes made in the substitute were merely verbal, and were proposed with the view of bringing the phraseology of the rule into literal conformity with the wording of the deed of trust.

The substitute was carried without a dissenting vote.

Adjourned.

WM. H. WAHL, *Secretary.*